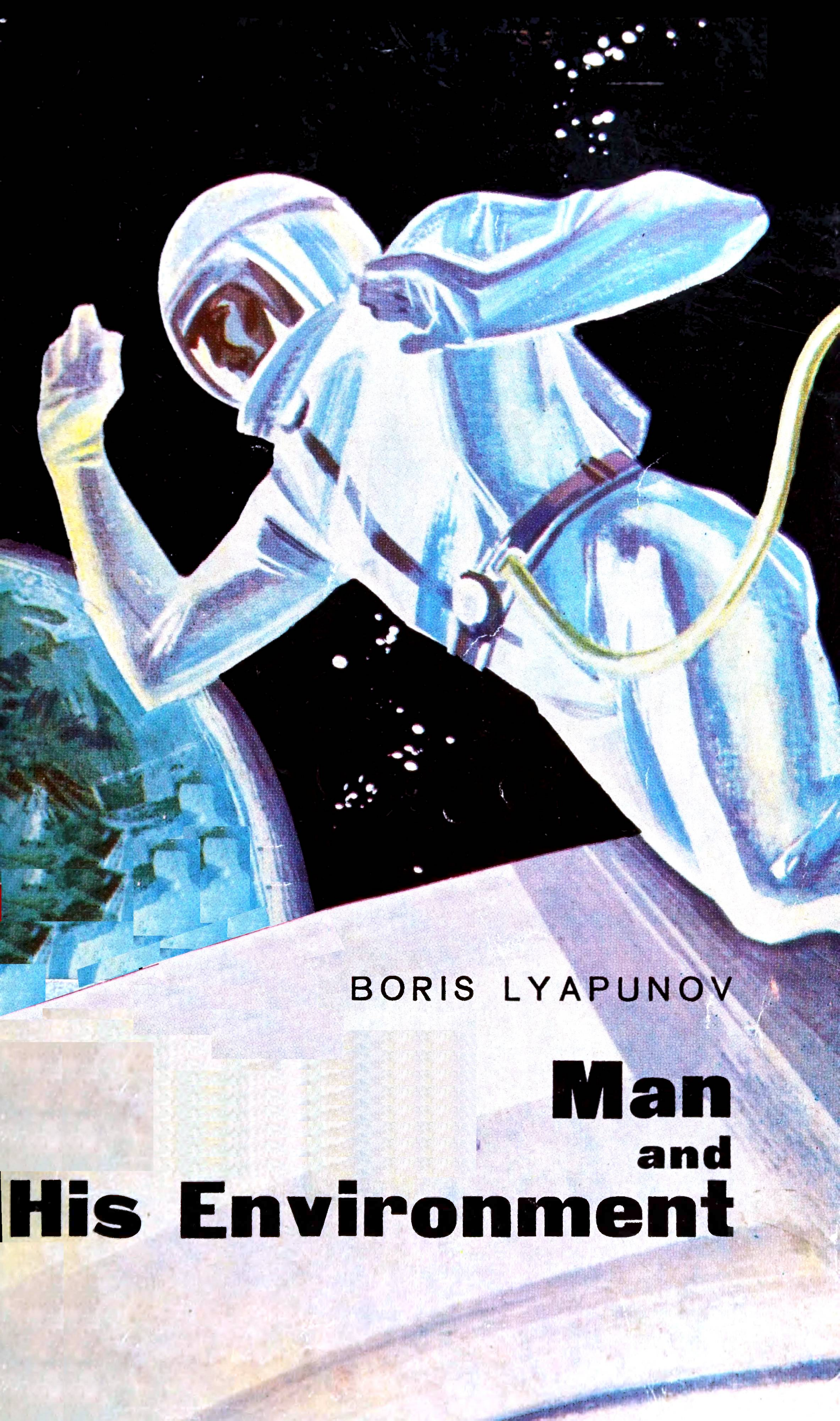

BORIS LYAPUNOV

Man and His Environment

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Some Notes on the Way
We Are Going About
Our Exploration
of the Earth's Interior,
the World Ocean,
the Atmosphere,
and Outer Space

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OUR PLANET'S "NEW LOOK"

People are prone to think that the age of great geographical discoveries is over and that henceforth any new discoveries will be made only in the cosmos. However, there is no justification for such an idea.

We do not intend to deny that our conception of the Earth has broadened as a result of man's breakthrough into the cosmos.

We learned, for example, that the Earth's atmospheric envelope extends from 2,000 to 3,000 kilometres outward and not a few hundred as we had thought. We knew—so we thought—that the Earth had just one natural satellite, but it appears that there are several, though belonging to different astronomical categories, such as radiation belts, dust clouds, and the long gaseous train which trails behind us like the tail of a comet.

Contemporary geography can claim no discoveries on a scale comparable to the geophysical discoveries in the cosmos, of course. No great new continents, no large islands, no hitherto unknown mountains remain to be discovered on our planet. But, on the other hand, submarine geography, which is a new branch of traditional geography, has revolutionised our conception of the Earth. Research in submarine geography, especially during the last few years, has sketched out for us the profiles of the invisible continent known as the ocean floor.

Still, discoveries are being made on land as well. And no mean discoveries at that. Perhaps the most outstanding example is Antarctica, for facts about this ice-mantled continent began to be learned only in the most recent times.

Many new discoveries have lately been made in South America, such as a waterfall much bigger than Niagara; another waterfall of such a height that the local inhabitants talk of water falling from heaven; a plateau cut off from the rest of the world like the one in Conan Doyle's famous tale; giant rivers winding through the jungles; lakes whose existence had not even been suspected.

There is but one logical conclusion: even a thorough knowledge of land and sea does not mean that we shall not continue discovering "blank spots", large and small, on the map of the world.

It may be said, at any rate, that we have only recently begun to get a true picture of the Earth as a planet. We repeat–as a planet, for it is now being studied in all its aspects as a cosmic body.

This new discovery of the world began by stages, and if only a part of the picture appeared the general outline could already be guessed. Automatic cameras were flown by rockets to great heights–a hundred kilometres at the outset, later even higher. The pictures taken showed the unmistakable curvature of the Earth and a part of its rim.

These early efforts were succeeded by sputniks and, later, by satellite spaceships which began to orbit the Earth, one after the other. It was then that the terrestrial globe was first seen as a whole.

Automatic meteorological stations began to overfly the Earth, their TV cameras yielding pictures of clouds over great spaces. These were a revelation for the meteorologists, who observed new types of cloud formations never seen before.

Such photographs now run into hundreds. The processes of cyclone and typhoon formation stood clearly revealed, and one need hardly stress the importance of these observations for the permanent weather reporting service that will be established in the future.

Manned spaceships are equipped with ordinary and motion picture cameras. The pictures they take show more than just clouds: they reveal mountain ranges and the shore lines of seas and oceans. The space pilots have produced brilliantly coloured fragments of a relief map, which, far from being just bits of marvellously beautiful landscapes, will serve as elements of a future general map of the planet Earth.

Current programmes for the exploration of the immediate cosmic space provide for the launching of hundreds of artificial satellites. Increasing attention is being given to projects providing for the construction of regular "space islands", or manned space stations.

Sputniks, or satellites, will perform the functions of meteorologists, cartographers and geodesists, helping to obtain more accurate data on the size and position of the continents and larger islands. It is to be expected that distance measurements on the surface of the Earth will greatly increase in accuracy, enabling science to settle once for all the moot question of continental drift.

The hypothesis of continental drift, current since long ago, has been the subject of heated debate. The answer to this problem will be furnished by a permanent system of geodetic satellites.

Satellites offer Earth scientists a remarkable opportunity to do more than see all of our planet and establish its true shape.

It has been known for some time that the Earth is far from a perfect sphere, being flattened to a varying degree at the two poles, while the equator is not a perfect circumference. It took the sputniks to establish the true shape of the Earth, which is more like a pear than a tangerine.

The geodetic satellites that orbit the Earth today are a far cry from the laborious toil of the geodesists of the past. Every new satellite launched means additional photographs for the picture library, additional miles of tape recording the wireless messages sent from these man-made moons.

Satellites enable us to see the terrestrial globe, note all manner of details upon it, measure it, observe the behaviour of the clouds and the movement of ice, and penetrate visually from the skies into the Earth's interior.

Geological satellites have also contributed to our knowledge of the Earth's interior.

A satellite's actual orbit generally deviates from its calculated orbit, varying from one revolution to another. Many factors account for this, among them the atmosphere, if the height is not too great, and the complex interrelation of the gravitational fields of other heavenly bodies. The chief factor, however, is the Earth itself, whose captive the satellite still

remains. For artificial satellites and the moon alike are held to their orbit by terrestrial gravitation.

Inasmuch as the Earth's interior mass is distributed unevenly the action of the force of gravity upon the satellite also varies. The pull of gravity may increase or decrease, and the true orbit deviates from circumference or ellipse. The measure of such deviation indicates the location and depth of heavy rock material beddings, and the presence of anomalies which may mean the presence of ores.

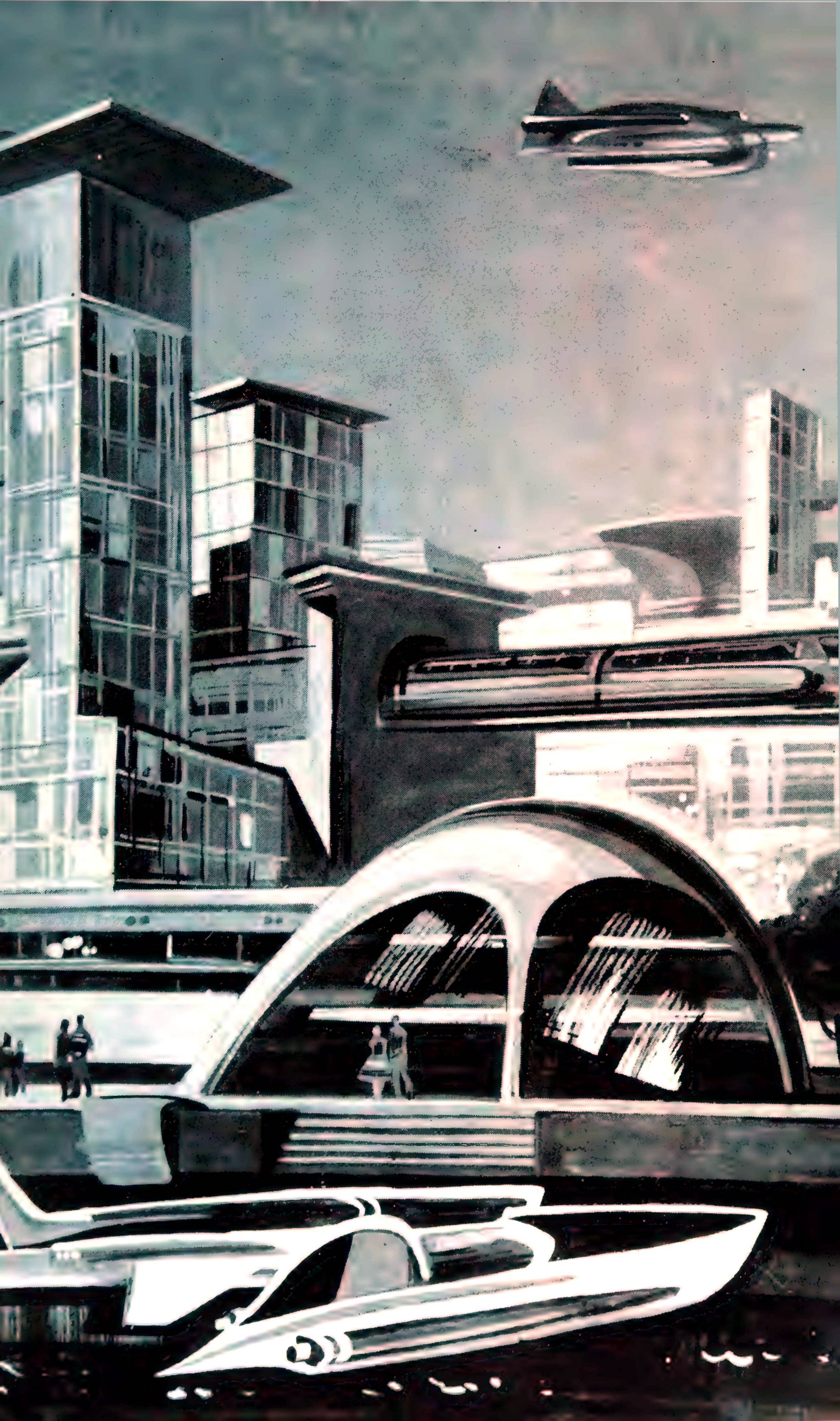
Observation from space shows very clearly that the greater part of the Earth's surface is covered with water. It appears that such observation from above enables us to survey the ocean bottom and subbottom strata, to probe the entire floor of the World Ocean, as it were.

Our present knowledge regarding the structure of the deep interior of the Earth, whose surface is 75 per cent water, is quite superficial. Echo sounding has been useful, of course, and will continue to be useful for mapping the ocean floor. But that is not enough. Nor is submarine drilling enough, representing but one approach to the study of the Earth's interior. Seismic waves, which penetrate hundreds of kilometres of the Earth's interior, will be supplemented with satellites for the work of prospecting.

This prospecting of the Earth's interior from the cosmos has only just begun, and it is too early at present to speak of any discoveries which may be attributed to it. Among the many riddles of the Earth, that of its interior remains the biggest. It would be wrong to assume, however, that no new discoveries have been made in this field.

A general conception of the Earth as a planet is beginning to take shape at a very slow pace. The interrelations between the various layers of which the Earth is composed, and those between the Earth and the universe which surrounds it are becoming revealed very gradually, though more and more definitely.

Only a very general description can be given at present of interrelationships between core and mantle (substratum); mantle and crust; ocean and atmosphere; atmosphere and cosmos; we know even less about the interrelations between cosmos and core. There is little evidence to confirm existing hypotheses concerning the nature of the deep interior, and even that evidence is indirect.



The nature of the core, i.e., the sphere lying within all the other layers of the Earth, is currently the subject of discussion. The idea of a hard core has been rejected long since, but the concept of a liquid core is also unreasonable in view of the exceptionally high pressure to which the core is subjected.

What, then, is the nature of the Earth's core? Contraction under the pressure of millions of atmospheres has most likely shattered the pattern, crushed the molecules, and turned the very atoms into a chaotic concourse of electrons, ions and nuclei. The temperature within the core, in addition, is very high.

Science has discovered a fourth state that substances may assume, i.e., plasma. Plasma is a gas free of whole molecules and atoms and containing only ions and electrons. It is possible that the substance of the Earth's core is just some such form of plasma, cold from the standpoint of nuclear physics, and extremely compact. This is merely a hypothesis, and one among possible others. One thing is certain, however: the substance of the core is unique, unlike anything else. Perhaps it is metal, for metals, being heavy elements, gravitate towards the centre of the Earth.

Another hypothesis is current, namely, that the varieties of material making up the Earth are basically one and the same kind of rock, only transformed under the action of pressure and temperature. The deeper down, the greater the contraction and the heat, changing the nature of the substance, which acquires the characteristics of metal without being metal and behaves like a liquid without being a liquid.

No definite solution has been offered so far, because no one has yet seen the rock material of the deep interior. We can only reason logically, deducing the unknown from the known.

We do know that superhigh pressures can actually unrecognisably alter substances with which we are quite familiar. When temperature is brought into play in addition soft and brittle graphite will turn into the hardest kind of diamond under such double action.

Creation of such an artificial diamond under the pressure of 200,000 atmospheres and at 4,000°C is tantamount to penetrating the outer mantle that underlies the crust, with the core still a long way off, however.

Artificial quartz is still another attempt to create a model of the rock material of the deep interior. It is more compact than the common quartz so abundant in the Earth's crust.

A likeness of the substance of the deep interior has thus been achieved, and the technology of the future will probably create the likeness of the substance of the core, which may be checked against the hypotheses current at present. Today's record in high pressure physics is over 400,000 atmospheres. An explosion engenders far greater pressures, but the phenomena characteristic of the split second in which an explosion occurs can be neither captured nor measured.

In the absence of knowledge regarding the nature of the Earth's core scientists have advanced some interesting hypotheses. We had assumed all along that the core should naturally be located in the centre of the Earth, but a novel hypothesis has recently been published, suggesting that the core is no longer in the centre of the planet and shifts around within it instead of "staying put".

Another hypothesis suggests that the electric equilibrium within the core has been disturbed. Electric currents are active inside it, and a kind of gigantic dynamo is running in the Earth's interior. If such is the case a magnetic field should exist, since there is a permanent association between electric currents and magnetism, and magnetic power lines should be present outside the core.

The assumption that there are magnetic power lines outside the Earth's core can be easily verified. The Earth is a gigantic magnet. It would be erroneous, of course, to ascribe this entirely to the core. What we can establish, however, is the importance of the core in bringing about this situation.

It must be admitted that the riddle of terrestrial magnetism remains unsolved. It may be due to the presence of iron ores in the crust, for they are natural magnets. On the other hand, it may be due to the Earth's rotation. As for the currents, it has been established that these travel through the crust, in the ocean depths, in the ionosphere, and generally in all the principal layers of the Earth, including the hard, the liquid and the gaseous.

Going back to the problem of the core, it should be pointed out that the magnetic field produced by it should stretch beyond the limits of near space. Its presence near the Earth has been conclusively established, for charged cosmic par-

ticles are being trapped in the inner radiation zones, created by terrestrial magnetism.

As rockets began to travel thousands of kilometres away from the Earth, instead of hundreds as in the earlier efforts, outer magnetic belts came to be discovered. Magnetometers detected a noticeable magnetic field even there.

That proved the hypothesis that the terrestrial dynamo continues to make itself felt far beyond all the layers of the Earth. Moreover, an intimate interrelation was detected between the various processes in the Earth's interior and those that go on in outer space.

* * *

Let us turn now to another world, hitherto unknown, whose discovery wrote a new chapter in the book of Earth sciences, a chapter, moreover, both extensive and important.

Our first acquaintance with it dates back to the 19th century, when regular soundings of the ocean depths were begun. The soundings were carried on at a snail's pace, however, and it would have taken centuries to complete the work if they had not been speeded up.

Dropping a weighted line overboard to determine the depth is not enough to form even a superficial conception of the bottom relief. Almost anything can be by-passed between any two soundings: a mountain, a submarine volcano, or a miles-long fissure.

That explains the age-old conception of the ocean bottom, which was thought to drop gradually as the distance from the sloping shore increases, levelling off into a vast plain. The oceans were thought of as contained in gigantic basins.

When soundings on the high seas revealed the existence of of deep-water depressions, this conception underwent a change. It took the echo soundings developed during the First World War, however, to reveal the actual relief of the invisible continent by producing a continuous record of the depths.

At the outset there were not enough echo-sounder records to give a sufficiently detailed picture of the invisible bottom relief. Moreover, the World Ocean is so vast that only the joint efforts of the scientists of many lands over a long span of time can radically change the traditional conception of the ocean floor.

Various important discoveries concerning our planet had been made, admittedly, long before the inauguration of the great effort undertaken by the geophysicists, known as the International Geophysical Year and represented by a miniature globe encircled by the orbit of a satellite over the abbreviation IGY.

Under the IGY programme a global study of the Earth was undertaken by scientists from many countries. Numerous rockets and satellites were launched and what amounted to an international fleet of ships sailed the seas and oceans. Indeed, the results of this joint scientific effort were so gratifying that it was resolved to put it on a continuous basis, substituting IGC–International Geophysical Co-operation–for the symbol IGY.

That the joint effort began with a study of Antarctica, outer space, and the oceans was not surprising.

A dense network of lines began to criss-cross the charts of the oceans, reflecting the voyages of research vessels. These ships covered hundreds of thousands of miles, making thousands of "stations" at sea to obtain water and bottom samples, make measurements, and take pictures. The bottom topography was recorded to provide profiles of the ocean floor, which was discovered to be no less intricate than that of the land surface of the Earth.

These efforts resulted in the first complete map of the Earth, revealing its true face. Absence of blue, which is used to denote the oceans, is a characteristic of the globe depicting the Earth in terms of dry land.

There are as many geographical marvels hidden beneath the water as there are on dry land.

So-called marginal trenches have been discovered in the proximity of the coasts, deep enough to engulf the highest mountains on the Earth's surface. Submarine mountain ranges have been discovered, comparable to those found on dry land.

Important space will probably have to be reserved in the textbooks of the future for discoveries in the realm of submarine geography, even if the account were limited to those made under the IGY programme. We refer to future textbooks because the work has not been completed and the bottom relief of the World Ocean has been studied only in part.

Among the latest discoveries is a giant fissure in the ocean floor 70,000 kilometres long; and a multitude of submarine mountains with flat, sliced off tops, such as are not to be found on land.

The submarine world seems to be a world of volcanoes. Thousands have already been counted, and the count is far from finished. Many of them are not extinct, and it is probable that submarine eruptions are more frequent than those on land. Sailors and inhabitants of coastal localities occasionally witness the appearance of new islands as a result of submarine volcanic activity.

Submarine earthquakes are also frequent, unfortunately. A submarine earthquake may be even more terrible, for it may produce a tsunami, or tidal wave, which, while hardly perceptible out at sea, may spell calamity for the seashore. A tsunami hits the shore, travelling with the speed of a fast-flying airplane, and wrecks everything in its path. Occasionally a dislocation of the sea floor engenders a shock wave whose impact may shatter a ship.

The areas where seismic activity is most frequent and volcanoes are particularly numerous are to be found along the fringe of the continental slope.

Run-of-the-mill submarine mountain range discoveries are now quite frequent, much more so than of those of exceptional size.

This holds true even of seemingly well-known stretches of ocean with lively traffic and numerous sea lanes, where the ocean floor remained until recently a veritable *terra incognita.*

To quote Roger Revelle, a recognised American authority, "We know less about the bottom of the Indian Ocean than about the surface of the Moon".

Indeed, we are now familiar with the reverse face of the Moon, while the exploration of the Indian Ocean by research vessels of many nations has just begun.

Progress has already been made. Thus, new mountains and mountain ranges have been discovered, among them one of volcanic origin, with several peaks; a number of deep-water troughs have been located; the ocean floor has been found to be carpeted with concretions of ferromanganese ore; and its waters appear to abound in food fishes in areas never fished before.

The ferromanganese ores do not begin to exhaust the list of things discovered by the deep-sea cameras and brought to the surface by the deep-sea trawls. A vast cemetery of shark's teeth has recently been discovered in the Indian Ocean, and the age of these relics is put at several hundred million years.

Such discoveries are of interest primarily to the geologists, who are already making a serious study of the best ways of mining ore under water.

The hard ocean floor, moreover, is covered with sediments, which have been settling over it for millions of years and are now buried under a thick blanket of silt and the column of water above. There are no rapid and powerful currents near the bottom, and the temperature never varies. Protected from any disturbance, the ocean bottom is ideal for the preservation of ancient relics.

One geological period followed another, leaving its record on the bottom of the ocean. Layer after layer added to this submarine record—a record of the ocean, the terrestrial crust, the atmosphere above it, and even of outer space.

These sediments are composed of the remains of marine life, from the smallest specimens to the largest, sinking from the upper layers of the water to settle for ever on the ocean floor.

They also contain interstellar dust penetrating into the atmosphere—fragments of meteoric substance which have come to rest on the bottom. These have been brought to the surface for examination and found to be minute spheres of undoubted extra-terrestrial origin.

The record of the ocean floor thus embraces the history of the ocean from its earliest days down to modern times. The ocean sediments are rightly considered to be a key to the past. When we learn to read nature's writing we shall be able to read the record of the earliest times.

In order to learn the story of the World Ocean we must find the answers to many questions. What was the Earth's climate thousands of years ago? Where were the magnetic poles located? What did the ocean look like then? What was the nature of its waters: as we know it now or different?

The answers can be found in the sediments. For only they contain the record of that faraway epoch before the appear-

ance of man, and can aid us in delving into the past that has left us no fossils of living organisms.

The Earth's magnetic field underwent changes, the magnetic poles shifted, and the changes were recorded in the bits of sedimentary rock. The pattern of these infinitesimal particles gives an exact picture of the magnetism of the relative period and makes it possible to reconstruct the past.

Penetrating into the sedimentary layers is like travelling in time. A bottom soil core 34 metres long has been obtained. When drilling in the ocean floor becomes possible the journey into the past will be continued, and we may reach the strata which formed the bed of the primeval ocean at the time when it first began to fill up with water.

Let us now turn to the problems of marine life.

According to Hans Pettersson, the Swedish scientist, there can be no life below 6,500 metres. Rather surprisingly, this statement was made as recently as 1948. Until quite recently, therefore, it was considered that no living being, including bacteria, which are the toughest organisms in the world, could stand a pressure of more than 650 atmospheres and perished when this limit was exceeded.

Refuting Pettersson's theory, however, the trawls soon brought to the surface specimens of marine life from depths in which they allegedly never could have lived. Bacteria were found in water and bottom samples taken from the ocean floor at very great depths. Scientists on board the Soviet oceanographic ship *Vityaz* caught a fish more than seven kilometres down, and it was not of the species that live at the greatest depths.

While we now have vessels capable of travelling over the sea floor in shallow waters, none have as yet been developed for travel at great depths. Bathyscaphs have made a few initial dives of short duration close to the ocean floor.

The results of their observations were a matter of good luck, of course.

On one occasion a fish was seen at four kilometres below. On another occasion a shark-like specimen was observed at a depth of eleven kilometres. A fish seen in the rays of a searchlight played over the sea floor eleven kilometres below the surface is rather convincing evidence of the ubiquity of life in the ocean.

The explorer who studies life in the ocean is confronted with countless surprises, especially those presented by the deep-sea fauna whose existence has been questioned.

Contact with the latter was established during the first bathysphere submergences to a depth of one kilometre, which caused a sensation in the scientific world.

It was during these submergences that the observer first saw through the bathysphere observation port the monstrous inhabitants of the realm of eternal night. He could not have been more excited if he had seen a Martian. What, indeed, *does* one feel when confronted by fantastic story-book creatures in the flesh?

They come in an endless procession of grotesque shapes and extravagant colouring running through the entire spectrum in all its possible combinations. Luminescent, flashing lights of different colours, and transparent, large and small, these deep-sea creatures, once beheld, upset all previous conceptions of the submarine world.

This submarine world, it appears, is also teeming with life. Here, too, a savage struggle for survival goes on. Hence the luminescent organs, huge eyes, monstrous jaws and long sharp teeth with which the deep-sea species are equipped.

Writers of science fiction dream up uncanny inhabitants of other worlds while here on our own planet, a world has been discovered such as no stretch of imagination can possibly conceive.

Many of the grotesque creatures seen some thirty years ago by the occupants of the first bathysphere have never been observed again. Other finds have been made, however.

Reports and articles began to appear about encounters with fabulous creatures in various parts of the world. A live pterodactyl was reported seen somewhere in Africa. A giant saurian had been glimpsed in a lake. A sea-serpent had been observed from a ship in mid-ocean. Age-old legends are revived, and rumours fly, one more marvellous than the other.

Let us sift out the facts, however, accepting only those that have been amply proved and merit belief.

A number of living fossils have actually been discovered comparatively recently by the scientists of various lands in the ocean where all life originates.

One of these specimens is a fish which should have been extinct 300 million years ago. Another is a mollusc which

has lived on the Earth since the palaeozoic period. Still another find is an entire new class of stomachless creatures doubtlessly belonging to the Earth's most ancient fauna.

Some of the bizarre creatures glimpsed by the scientists in the darkness of the ocean deep have been encountered again and again and described in scientific catalogues. Naturally, these specimens and other deep-sea creatures that have been seen through the observation ports of bathyscaphs in the course of the few dives so far effected do not exhaust the variety of marine life. Deep-sea trawls continue to bring up ever new, hitherto unseen inhabitants of the ocean.

We have had merely a glimpse of the unknown. Our penetration into the depths of the ocean has just begun.

Life pervades all the zones of the ocean, from the surface to the bottom of the deepest trenches, that is, even the places where seemingly no life should be possible. This means that there is constant circulation in the ocean throughout the water masses, for otherwise no oxygen could reach the greatest depths. Common natural laws govern the World Ocean, therefore, and everything in it is embraced in a pattern of relationships.

It might seem at first glance that the extreme complexity of the processes that go on in the ocean will never be unravelled. It is like an equation with too many unknowns, that even the most modern electronic calculating machine cannot solve. The continuous movement, continuous change, and ever-lasting clash of various forces are such that it is impossible to predict the outcome, just as it has been impossible—so far—to predict an earthquake.

There should be no room for pessimism even in this regard, however, for it may already be definitely stated that oceanographic and seismological forecasts will be made some day, like the long-range weather forecasts of today.

Methods of predicting imminent earthquakes on the basis of barely perceptible signs are currently being developed. Our ability to make such predictions will depend on a number of very important factors.

In the first place, increasingly sensitive instruments have become available in recent years, and much that had previously passed unnoticed has now been revealed.

Thus, it has been established that minor disturbances are much more frequent than it had been thought, and that the

area of seismic activity includes plains and long quiescent platforms, regions, in other words, where no earthquakes should occur. Earthquakes of considerable magnitude, it appears, are preceded by so-called foreshocks, or minute slips of the crust; they may be likened to the infrasonic signals that serve notice of a developing storm.

Another factor will be penetration of the unknown in quest of that very unknown. When we learn to lower our seismographs into deeper and deeper drill holes, we shall be able to capture warning signals in the immediate vicinity of the source of danger.

Creation of a system of artificial satellites and construction of a permanent extra-terrestrial station will permit us to establish a global weather service and a solar service. As to oceanography, a great advance will be achieved when a network of oceanic observation stations is set up and continuous study of the surface and the deeper strata, i.e., intermediate, deep and bottom, is established.

All this is for the future, but the groundwork must be laid today.

Many other discoveries have been made in the ocean.

Who would have thought, for instance, that there exists in the ocean a regular pattern of powerful underwater currents, submarine rivers, so to speak? Quite a swift and powerful current, for instance, has been discovered to flow below the Gulf Stream, and another current still farther down, constituting a multilayer stream. Many such currents have already come to light, although the quest has really just begun.

The age of the bottom water in the deepest oceanic trenches has also been measured. Initially opinions differed: American scientists held that it takes hundreds or even thousands of years to accomplish a renewal of water, i.e., a thorough mixing of all the strata. Soviet scientists suggested a much shorter period.

The duration of this process acquired vast importance for mankind all at once, for it will determine whether or not it is permissible to dump radioactive waste on the ocean floor. The Americans maintained that nature itself had provided such a submarine cemetery for the purpose; contamination, they said, would never actually reach the upper strata, even if the containers were to become corroded.

It developed that they were wrong, however. There are no stagnant waters in the ocean. The contaminated water will rise to the surface, sooner or later, but within the lifetime of one generation. Given the current rate of development of the atomic industry the world over, the great potential danger of such a method of radioactive waste disposal becomes self-evident.

A comprehensive picture of submarine currents, which are as ramified, probably, as the rivers on land, is far from complete. Only a few current velocity measurements have been taken here and there at random depths. In all probability these invisible deep-water streams will appear on the ocean charts only when permanent anchor and bottom stations are established.

Automatically operated submarine laboratories, which are currently being set up, may possibly be used for this purpose.

When the pattern of deep-sea circulation is fully understood the problem of its reorganisation may be approached. This circulation pattern largely determines climatic conditions. Vertical currents bring cold water up to the surface, together with mineral diet for seaweed. Currents are therefore of great importance to the organic productivity of the ocean. It is not surprising, therefore, that the most prolific ocean pasturages and greatest fishing grounds should be found precisely where these vertical currents are strongest, at the convergence of cold and warm waters.

Ambitious projects envisaging the use of atomic reactors to heat abyssal waters have been developed. Warm water, being lighter, would rise to the surface, bringing with it an abundance of food for the ocean population.

Seeking to discover the causes of various phenomena, and attempting to build harmonious hypotheses out of possibly unrelated facts, we occasionally arrive in a blind alley; for the obvious, the commonplace, has too strong a hold over us, and we are slow to grasp the significance of the latest discoveries, especially when they are not particularly striking or sensational as, for example, the quest of the snowman, or yeti. Unsensational scientific events are seldom written up in the newspapers and are not widely known.

Such has been the fate of the recent discovery of a new population on our planet, a discovery made possible by hard work over a very long period of time.

This population permeates the World Ocean from pole to pole. Its existence, however, was admitted only after researchers, seeking proof, had visited explorers on their polar drifting stations, ranged over the seas and taken water samples at various depths. Points denoting microbiological stations make a heavy pattern on ocean charts.

Findings everywhere support the conclusion that this population, invisible to the naked eye, exists wherever there is water. As a matter of fact it has been discovered even in soil samples obtained by probes from the bottom at the greatest depths.

We have known that there are microbes all around us, that they are tough and able to survive in conditions which are inevitably fatal for other forms of life. We have long known that microbes–harmful and harmless–live in the soil and in the air, and are always with us whether we like it or not. But the discovery of microbes surviving in places where a pressure of several hundred atmospheres is registered came as a complete surprise.

Plankton, seen through a microscope, presents a sight of extraordinary beauty. Every drop of water contains living organisms to create which nature must have been endowed with the gift of a mathematician and the talent of a goldsmith. One is held spellbound by their architectural elegance of form, their geometric perfection, their endless variety of combinations.

The microbe world of still smaller creatures presents a picture of no less splendour. Powerful microscopes, electronic instruments included, are needed to see them and to admire their filigree daintiness.

It is not only the beauty of these infinitesimal creatures that has attracted scientific attention, of course: it is rather the manifest significance of microbes in the diet of the other, non-microscopic population of the ocean that is responsible for this interest.

They, the microbes, are destined to be an intermediary between the living and the dead; they are the ghouls that transform the organic detritus, drawing nutrients from the steady precipitation of dead organisms settling on the ocean floor.

Simultaneously, however, they are, collectively, the kitchen

where the food is cooked that is needed by plant and animal life alike. Their function is to absorb into the continuous life cycle that which would otherwise drop out of it and be wasted.

It would be wrong to claim, much as we should like to, that the science of marine microbiology has thus come up with the final answer, for microbial forms continue to be discovered which modern microbiologists have never seen before.

One of these are bacteria with a peculiar anatomy, having a head resembling a cluster of tiny beads. They are present in bottom sediments, too, which means that they are living fossils which must have lived on our planet millions of years ago. Since their body contains iron and manganese it might be conjectured that they are responsible for the existence of ferromanganese concretions.

Another form are ultramicroscopic virus-like organisms.

Still another are bacteria whose existence, apparently, may be imputed to the energy released by radioactive disintegration.

Absorbingly interesting and far-reaching interrelationships are being established, to which outer space is a most important contributor, and it is probable that in the long run many of our notions regarding the nature of the biosphere will have to be reconsidered.

The microbiota is apparently omnipresent. It is to be found in the ocean, in the soil, and above it, right up to the threshold of the stratosphere. The habitat of microbes reaches many kilometres into the terrestrial interior and many kilometres out into space.

There are a number of other facts, however, which must not be overlooked. Microbes are the only living organisms that can survive extreme conditions, such as temperatures approaching absolute zero and temperatures of several hundred degrees; vacua approaching those of interstellar space; and pressures exceeding 1,000 atmospheres; not to mention their indifference to the absence of oxygen. They tolerate dehydration, and they will survive days of boiling in water. Radiation, which is lethal for other organisms, is harmless for these microscopic creatures, for nature has provided them with some special kind of immunity against colossal doses of radiation.

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Let us leave the ocean now and turn to outer space. Let us imagine a planet deprived of water but provided with some sort of a substitute. Let us also assume the presence of oxygen even though in negligible quantities and hydrocarbons similar to those found on the Earth. How would a microbiologist evaluate such a situation?

He would probably claim that microbes could be present even on a waterless planet, because some other solvent could replace water. Some microbes, like plants, are capable of photosynthesis. We may assume, in all probability, that the presence of oxygen on a planet denotes the presence also of a microbial population.

Hydrocarbons brought to the Earth in meteorites lead us to conjecture the existence of some kind of microbes far beyond the fringes of our world.

In former times the necessary presence of various forms of life on various heavenly bodies was arrived at by logical reasoning. Evolution, it was held, may have developed there along different lines, leading to different results. The presence of microbes, however, provides the first facts for the laying of the foundation upon which the edifice of a new and broader approach to the riddle of life is to be built.

Until recently we were content to be bound by the limits of our familiar, terrestrial sphere. Now, however, we have begun to reach out into the endless spaces of the universe in our efforts to solve the problem of the origin and development of life.

An assumption is no more than just that. The presence of microbes on other heavenly bodies is so far only a hypothesis, a guess, a product of logical speculation, unconfirmed experimentally.

All that notwithstanding, the container of the Soviet lunar rocket was subjected to sterilisation in order to preclude any contamination of a possible alien population with our terrestrial microbes. And it is more than likely that those cosmonauts who will have trod the surface of the Moon or other planets shall have to submit to a quarantine before landing on the Earth so as to exclude the possibility of bringing back any microbes from outer space.

Our conceptions of the world around us are undergoing a change.

The true aspect of the cosmos is gradually being outlined—a living cosmos, though the "life" referred to here is used in a special sense.

Far beyond the confines of the Earth an intricate play of various forces goes on ceaselessly, day in, day out, bringing into continuous movement and constant interaction among themselves and with the Earth such phenomena as electric and magnetic fields, gravitational fields (graviton particles, possibly, whose existence is still debated, though not denied), charged and neutral electric particles, visible and invisible rays, streams of familiarly tangible meteoric particles, cosmic dust clouds, etc., etc.

Only the echoes of the immense processes going on somewhere in the universe reach us here on the Earth, reliably shielded from the breath of the cosmos as we are by our gaseous envelope, which, by the way, is not our only protecting shield of armour. The magnetic field of the Earth, engendered in all probability by the terrestrial core, acts as a magnetic shield which the insufficiently energetic particles are unable to pierce.

We watch the lights of the polar aurorae and hear the cosmic noises intruding into our wireless reception and the sound of tiny meteorites hitting the jacket of a satellite or rocket as relayed by the microphones mounted therein.

Meters sent up into outer space are overwhelmed, unable to keep track of the particles, when solar flares occur. Violent oscillations appear at such times on the tapes of Earth-based instruments set to record the behaviour of radiation belts from rocket-relayed data. All of which goes to explain why satellite spaceships are shielded from radiation and the cosmonauts are provided with special chemical preparations to protect them from radiation sickness.

Just as the ocean forms a part of our planet, so the latter is a part of the cosmos. An ocean-cosmos relationship is an established fact. Therefore, whatever occurs in outer space is far from a matter of indifference to the vast body of water that covers the greater part of the Earth's surface. If the past, the present and the future of the Earth are to be understood, the laws governing the World Ocean must be studied.

Ships sailing the seven seas year after year were first to discover the marvellous realm of the oceanic depths. Wherever they went, research vessels obtained samples of the water

and cores from the ocean floor, clocked the speed of the currents, and studied the flora and fauna.

Since the work was carried on over a wide area a bird's-eye view was obtained, which is the only proper view in respect of a vast natural element with its pattern of all-pervading interrelationships. The task of science is to untangle these relationships and reveal the nature of the World Ocean seen as an integral mechanism of global proportions.

There is a permanent link between the World Ocean and the Earth's solid mantle and gaseous envelope. Water evaporates from the surface of the seas, consuming in the process one-third of the solar energy that reaches the Earth. Nearly 500 million cubic kilometres of water evaporate annually, bringing moisture to the land and the atmosphere; and rivers and precipitations return it to the ocean.

Thus, the Sun, our nearest star, 150 million kilometres away, exerts its influence, through the ocean, upon the life of the Earth's atmospheric envelope and therefore upon the mechanism of weather, and the circulation of countless water drops that leave the ocean only to return.

Interaction between the two elements—atmosphere and water—presents an intricate pattern.

It is not merely a matter of moisture transfer. The Earth's atmospheric envelope and mantle of water serve as a kind of canopy which prevents the heat brought by the Sun from escaping back into outer space. A sliding heat balance is maintained as a result. The ocean, like the atmosphere, helps retain the Sun's bounty, and it is hardly necessary to explain what this implies: deprived of the heat furnished by the Sun, the Earth would soon turn into a cold and lifeless desert.

The Sun could never warm the Earth, as a matter of fact, if it were not for the ocean. The ocean is responsible for the relative mildness of the Earth's climate. V. Shuleikin, Soviet scientist and academician, offers interesting figures to illustrate the situation. It appears that, but for the ocean, the mean temperature at Leningrad would be 52° C below zero! But for the ocean, the climate all over the world would be as rigorous as in Antarctica.

The Earth is a tiny speck in the infinite spaces of the universe. Which is all the more reason why we should be proud that the human intellect is penetrating deeper and deeper into the farthest regions of the universe, adding to man's com-

prehension of phenomena, relationships and laws on a cosmic scale, far exceeding our terrestrial limits.

Our planet is taking on a new aspect, and the veil which has concealed its distant past is slowly being lifted.

The controversy over the origin of the Earth and other planets continues unabated. The proponents of the concept of spheres initially molten and later cooled, whirling around the Sun, have suffered a defeat, and a diametrically opposite concept has gained ground, according to which the planets were cold initially and became heated later, and that their original source was a gas-dust cloud, rather than igneous-liquid stellar matter.

The latter hypothesis is better able to explain the peculiarities of the structure of the solar system today. This is not to say that the explanation is complete; new facts must therefore be searched for in order that all the questions may be answered.

It is possible that cosmonautics may come to the aid of cosmogony in this quest. So far, we have had to sit and wait for chance meteorites to bring us news from faraway worlds. Yet the possibility of visiting the Moon and other planets would be of inestimable value for historic geology. Even now, before the era of interplanetary travel has begun, geology has rightly come to be regarded as a branch of a much broader science, the science of planetology.

There is another question, equally disturbing and also connected with the origin of the Earth.

How old is our planet? We must turn to the atomic clock to get the answer. The time required for the radioactive disintegration of elements in rock has proved to be a measure of great exactness. Nature winds this clock, and nothing can affect its movement. It has helped us to establish that the age of our planet is 2,000 million years greater than hitherto believed.

This figure, which practically doubled our planet's age, was soon revised, however, thanks to improvements in atomic clocks and the discovery of other radioactive geological time-measuring instruments.

Examination of rock found on the ancient Kola platform produced another surprise: time reckoning by the new potassium-argon method resulted in the truly astounding figure of 6,500 million years as the age of the Earth.

One is inclined to wonder when we shall finally unravel the cosmic biography of our planet.

Its upper age limit is known: it is determined by the Sun. There is only one Earth and an endless number of suns, among them heavenly bodies of various ages, in various stages of their existence. The life of these sun-type stars has been sufficiently thoroughly studied by astronomers. Their ages and even the ups and downs of their future history are already a matter of knowledge. Geochronological details will have to be filled in, taking the age of our Sun as a point of departure.

The most ancient history of the Earth will be gradually reconstructed: its birth, childhood and youth will no longer be a mystery.

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We come now to a question which is of extreme interest to all of us: what are the origins of life on the Earth? A host of conjectures has been advanced on this point.

According to one conception, increasingly complex molecular protein structures finally resulted in a transition from matter to a living organism. The evolution which produced *homo sapiens* began with a regrouping of atoms, a transition from hydrocarbon molecular chains to simple and, later, more and more complex proteins.

According to another conception, life on the Earth is of exogenous origin, deriving from somewhere in the universe, rather than having its source on our planet. Life, in this view, had existed in outer space for thousands, possibly millions and even thousands of millions of years. It is pointed out that only spores—microscopic carriers of life that they are—can survive for any length of time in a state resembling anabiosis, retaining their viability in the absence of moisture and at extremely low temperatures. Arriving on our planet (still according to this theory) they came to life again and began the million-year-long climb up the ladder whose topmost rung is occupied by man.

A different theory prevails in science currently, however, which rules out chance as a factor determining the origin of life. Life, according to this theory, is engendered necessarily when the required conditions are present.

The three terrestrial mantles, i.e., solid, liquid and gaseous, plus solar radiation are the preconditions for the emergence and development of a biosphere suitable for the generation of life (biogenetic sphere).

With the passage of time our planet created a shield of its own against the deadly breath of the cosmos, effected a differentiation of land and ocean, and, at a certain stage, engendered complex hydrocarbon combinations which are the source of organic matter.

The biogenetic sphere, in turn, has changed under the impact of living matter; so that the habitable Earth of today is the product of the biogenetic sphere, which is closely linked with the cosmos.

Modern science is drawing nearer and nearer to the truth in its quest thereof, producing new hypotheses as nature furnishes it with new facts, hitherto unknown.

We must ascertain whether the organic substance discovered in meteorites may not be a trace of living matter and whether it may not have arrived upon the Earth from outer space.

We must analyse the seemingly paradoxical hypothesis that life may have been engendered in association with petroleum.

It has been established beyond doubt that the primary gas-dust cloud, which served as stock for the formation of all the planets, contained hydrogen and carbon. Incidentally, it has been also firmly established that hydrogen is the commonest element in the universe: the radiation of ionised hydrogen is quite emphatic in signals emanating from outer space and captured by radiotelescopes.

Is it possible, then, that hydrogen and carbon serve as raw material for hydrocarbon molecules? Petroleum is a mixture of various hydrocarbons: might it not be the raw material of proteins, or stock for primary living matter?

Life on other planets may require other essential preconditions, such as the presence of silicon in lieu of carbon, nitrogen or even noble gases in lieu of oxygen. This is mere speculation, however, even though not as fantastic as it may appear at first sight.

Life exists in the universe, and the forms it has assumed on our planet are not the only possible ones: other forms may exist.

Incidentally, we have strayed too far away from our own planet. While many discoveries have already been made, it is still a largely unexplored planet. In this cosmic age of ours, however, science is also developing at a cosmic speed, and it should be hoped that the lacunae in our knowledge of the Earth and the universe around us will soon be filled in.

UNANSWERED QUESTIONS

How many different worlds coexist in the greater world which we call the universe, and what does the term comprise?

Back in the days of humanity's childhood the answer to such a question would have been very simple: there is only one world, of course, and it comprises everything that is around us and speaks to our senses.

This simple conception long remained prevalent and sufficiently firmly rooted. The discovery of a world of microscopical organisms in a drop of water therefore came as a complete surprise; and the mountains on the face of the Moon and rings around Saturn, when first seen through a telescope, caused astonishment.

Each succeeding step into the newly discovered macro- and microscopic worlds served to extend their respective limits. One of the two worlds, having its beginning on the Earth, plunged outward into the infinity of the universe. The other led from molecules and atoms to other ultramicroscopical particles, and the atom appeared to us as a complex system resembling the Sun's family, where the nucleus is the Sun and electrons double for the planets.

A complete and comprehensive concept of the macro- and microworlds had been apparently offered and had found general acceptance.

The classification of nature into living and dead, into matter organic and inorganic also seemed immutable. The concept of the universe as a whole at the break of the century gave no sign of the discoveries that were to upset established principles in the same way that the discovery of Copernicus had done.

No one, certainly, denied the possibility of revision, adjustment, or amplification, even of substantial magnitude, in particular instances, in various fields of science, such as astrono-

my, physics, chemistry, biology, etc. The possibility was there, but only within the framework of the established concept.

Mendeleyev's Periodic Law, which introduced system into all matter with reference to the elements that compose it, did not transgress the limits of that established conception. Nor did the succession of discoveries of species, groups and classes of plant and animal life impinge on the whole structure of concepts regarding the organic and inorganic worlds.

Nevertheless, new facts accumulated gradually, and it became increasingly difficult to fit them into the orderly pattern.

They simply wouldn't fit into the places ordained for them, no matter what interpretation they were given. In the beginning, clever hypotheses helped reconcile new findings with the old theories in certain cases, but this became more and more difficult and led to crises.

Natural radioactivity, which was discovered early in the 20th century, undermined the simple nuclear-electronic concept of the atom. The Einstein theory upset all previous conceptions in regard to time and space. Our galaxy was discovered to be a mere part of a great stellar universe, and a long series of astronomical discoveries changed our ideas concerning the structure and development of the universe. The dividing line between the animate and inanimate, it appeared, is less definite than it had been supposed, and some forms might be quite properly classified with either.

Observation techniques developed immensely in the meantime, and the field of experimentation expanded. Invention of the optical microscope was followed by that of the electronic and, later, the proton instruments, and the world of viruses, creatures of ultramicroscopic size, became visible in addition to that of the microbes; and finally we were able to see the molecule and the atom.

Telescopes increased enormously in size and power; spectroscopy, photography and electronics were developed; and the range of visibility increased to 6,000 million light years. Radio telescopes were invented. Astronomy of the invisible was developed: man could now observe not only the visible rays of the universe but also its infrared and ultraviolet rays, the fluxes of electromagnetic radiation released by radio-stars, radio-nebulae and radio-galaxies. This was a kind of

new discovery of the universe, and the metagalaxy, which constitutes a now familiar part of the universe and comprises roughly 1,000 million galaxies, now appeared to us increased twofold.

Nuclear physics, with powerful accelerators now at its disposal, succeeded in making many new discoveries which revolutionised our former conceptions regarding the nature of matter. Just as we were hard taxed to find names for newly discovered asteroids in the past, so now we could scarcely keep abreast of newly discovered atomic particles.

These particles appeared endowed with the most extraordinary properties: superhigh-energy particles were discovered as well as low-energy particles, particles having no charge and capable of piercing the entire mass of the Earth.

Finally, discovery of the positron in the cosmic rays meant a qualitative advance: this was the first anti-particle, the antipode of the long-familiar electron. Discovery of other anti-particles followed and later the creation of artificial anti-particles was achieved.

It is perfectly logical, therefore, to assume the existence of an entire anti-world, i.e., anti-matter composed of anti-particles; and even to pin extremely practical hopes upon it.

To bring the matter home succinctly: the heating value of anti-matter fuel is 1,000 million times greater than that of coal or petroleum and 1,000 times greater than that of nuclear fuel as it is known today.

A different item of information could be supplied by the constructor of the spacecraft of the future. He would tell us that anti-matter could furnish enough energy to power a flight to the nearest stars and even farther. Stellar flight requires a vast supply of power. It is eminently logical, therefore, to turn to anti-matter as a source of power for such flights; but that is for the future, of course.

Production of anti-matter might be organised on some asteroid. It would have to be kept in magnetic containers; the magnetic field and the interplanetary vacuum would insulate it from any contacts.

Ordinary matter would be the other component of this fuel and would be furnished by the mass of the asteroid. The energy engendered as the result of the encounter of particles and anti-particles would cause the asteroid to leave its cir-

cumsolar orbit and travel beyond the limits of our planetary system, towards another star.

A journey into the micro-universe thus turns out to foreshadow one into the mega-universe.

While we have been using the plural forms of "world" and "universe", it is more correct to stick to the singular, for all our discoveries have brought nothing but various aspects of the great and single entity which is comprised in the concept of matter and manifests itself in a multitude of ways.

Man, too, is a part of this entity. Living and thinking matter is now seen in a different light. In a sense, a new world has been discovered here as well. New means–new results. Bacon's words are doubly true today, when refined research methods make it possible to achieve the impossible.

One has only to recall some of the great scientific achievements of the current century, such as measuring the energy of a single living cell; detecting the least perceptible biocurrents in a living organism; analysing step by step the complex chemistry of an organism, noting the hitherto unperceived aspects of its life; observing and photographing through a specially constructed microscope a living brain cell; delving into the greatest secrets of animate matter and undertaking to solve the riddles of the brain, a natural cybernetic machine more perfect than any similar man-made instrument.

It is too early to speak here of any practical consequences, save in the field of medicine. Still, we are reminded of the possibility of heredity control (an approach to the problem has already been initiated), and of the transfer of biological currents across space, which is already a reality (the biological-current-operated arm, for example), and will find application in the future in thought-controlled machinery.

When we shall have become better acquainted with animate nature and achieved an understanding of ourselves, we shall be able to discuss the problem of regenerating the organs of the human body and mobilising the vital resources latent in the organism. What this may lead to is so far a matter of pure speculation.

Science is one the threshold of an event of the greatest portent, in all probability. It is not the transformation of one element into another that is expected, nor the appearance of some kind of plant or animal hybrid, nor the creation of

some artificial mineral or non-existent material: this time it is expected that a living cell will be created.

We have learned to artificially reproduce the elements of "inanimate" nature; we have obtained plasma resembling the substance of stars; step by step we have achieved proteins in our laboratories; and it is possible that the great day is no longer far away when, duplicating nature, we shall create life out of inanimate matter.

There is no use trying to list all the achievements of science. Were the imaginary inhabitants of some other planet to arrive on the Earth—a favourite topic of science-fiction—we would have something to show them.

Yet there would be many seemingly simple questions which we wouldn't be able to answer.

Supposing we were to be asked whether we knew what is happening on neighbouring planets; or whether we were familiar with the inner structure of our own planet and had solved all the riddles of the ocean, the atmosphere and the adjacent part of outer space, or whether we had thoroughly studied everything that is to be found on the Earth's surface and understood the nature of the relationships between land and water, air and water, land and air, and Sun and Earth; and whether we could reply to all the innumerable "whys" suggested by the working of so complex a cosmic mechanism as the Earth.

We should have to admit that there still remain a great many things to find out.

We should have to plead ignorance of what goes on upon the neighbouring planets, for they are all still very much of a mystery to us.

Thus, students of the solar system continue to be concerned about the number of these planets: are there nine or more than nine of them? There is no reference here to the possibility that a planet called Phaeton revolved long ago between the orbits of Jupiter and Mars, and then disintegrated, leaving the present cluster of asteroids. The reference is to a tenth, trans-Plutonian planet which may exist at the present time.

This so far unknown farthermost planet would be probably some 10,000 million kilometres distant from the Sun. The question is, does it actually exist? That is one of the questions which modern observation techniques are unable to answer.

The theoreticians have been groping for an answer, and there is no doubt that the joint efforts of astronomy and cosmonautics will one day come up with the answer.

Why does Pluto, a minor planet, keep company with a group of giants? Perhaps it had been Neptune's satellite once upon a time? It is possible that the attraction of that hypothetical Tenth had disrupted that relationship and the Sun had acquired another satellite as a result. Still, the origin of that asteroid cluster between Jupiter and Mars continues to be puzzling.

Why do some satellites of the planets of the solar system rotate in a reverse direction? Why this exception to the general rule? What makes Phobos, the nearest Martian satellite, travel over its orbit at so fast a clip that it rises and sets twice each Martian day?

We are at a loss to explain a great many things even on the Moon, which is less than half a million kilometres away—a mere trifle so far as cosmic distances are concerned.

What is the nature of its crust? What kind of rock makes up its surface? What are the "light rays" that spread out from the craters for thousands of kilometres? And the spots that appear and disappear on the Moon's pale surface?

The questionnaire is long, and many, many answers are lacking, whether in regard to the Moon or the planets.

There is much to be learned about Mars and Venus; especially the latter. A great deal may only be assumed, and that only with varying degrees of probability.

Mars, for instance, has been observed by astronomers over a very long time, and has been the object of controversy for an equal period. With the possible exception of Venus, no other planet in the solar system has aroused such violent discussion or so much hope among those who seek to discover life on other worlds.

The presence of an atmosphere on Mars is unquestionable, but what is its nature? It contains no oxygen, seemingly, nor water vapour. Or have we simply failed to detect them? Perhaps they will be discovered by future automatic stations or spectroscopes sent up into space.

At present we can only speculate. We do not know the nature of the Martian atmosphere, whether it is nitric or composed of heavy gases. What is the nature of the purplish haze that draws over the planet from time to time? Perhaps it is

an agglomeration of ice crystals forming and dissipating alternately in the cold, rarefied atmosphere; or is it something else? The answer is still to be found.

There is much that is puzzling on the surface of Mars as well, besides such problems as the origin of the "canals" that form a grid on the face of the planet or the possible existence of plant life and perhaps life on an even higher plane of development.

What, for instance, are the mysterious darkish spots or the bright flares observed on the planet's surface? What about the spherical caps at the Martian poles: are they hoar-frost, snow, or ice? Is there water on Mars, and if so, how much? Opinion differs on this score, ranging from the hypothesis of a practically waterless planet to the concept of a planet covered with a thick crust of ice powdered with dust.

Lately we have begun, or barely begun, to be exact, to draw aside the veil of mystery shrouding Venus, another of our next-door neighbours.

The space station which passed in the vicinity of Venus a short while back reported a temperature of $+400°$C thereabouts. We are not certain where, exactly, this temperature obtained: on the surface of the planet or in the upper layers of its atmosphere. Are there any oceans on it, or is it an endless desert? What is the cold spot detected over the planet's south pole by Mariner-2? We still have to accept some one of the hypotheses regarding the nature of Venus.

Whether we look at the ring of asteroids, the giant planets, the planet nearest the Sun, Mercury, or the one farthest from it, Pluto—we run into something we neither know nor understand.

Our knowledge of the Sun and other stars is also far from complete, as a matter of fact. Phenomenal supernova outbursts have recently been observed. The relative position and shape of hundreds of thousands of star clusters, or galaxies, continue to astonish astronomers.

Much that is currently observed in outer space simply doesn't tally with our old conceptions. It is possible that we are on the brink of still greater discoveries; new, unknown forces and processes operating in the mega-universe may come to light.

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Let us leave the stellar spaces, however, and go back to our own planet, where we may also find secrets yet to be read.

To begin with, let us consider the ocean.

It is often said that the ocean is a treasure-house of all sorts of mysteries, problems, that is to say, of vital importance to us rather than abstract, which must be solved.

Efforts are being made to reconstruct the true relief of the invisible ocean floor. How did it form, and when? It is very important to know the answer if the history of the Earth and analogous planets is to be learned.

Neither the ocean floor nor the deep-sea flora and fauna have been sufficiently studied, or fully discovered, as a matter of fact.

Looking at the fantastic denizens of the deep brought to the surface by trawls or photographed in their habitat, one is inclined to wonder what makes for such outlandish (i.e., from our standpoint) forms. No satisfactory explanation has been found.

When we describe these creatures of the deep we still have to use such words as "seemingly", "possibly", or "in all probability". Yet perhaps the greatest mystery is why such widely different characteristics develop in this deep-sea life in the same conditions.

Zoologists are unable to explain why a certain species is to be found only in a certain locality, nor how some typically deep-sea species are able to survive in the upper layers of the ocean.

To mention another curious fact: some marine animals feed on bottom soil. They belong to the fauna of the lower layers, yet, quite incredibly, this circumstance has left upon them no particular imprint such as it has on other inhabitants of the deep. The only characteristic that they share with these others is the absence of colouring. This exception to the general rule has yet to be explained.

There is really no end to such questions. Here, for instance, is a very simple fact that every oceanographer has observed: the fauna of the upper layers is characterised by brilliant colouring. What for? To attract the enemies? That can hardly be the purpose. There *must* be some reason, because there is a reason for everything, but we have not discovered it as yet.

It is quite evident why animals of the abyssal fauna should be bioluminescent: in the realm of perpetual darkness they must have a lantern of their own to reveal a source of danger or to lure food. One wonders, however, whether these lanterns may not have other uses than merely to provide light.

Blind fishes are known to exist, though they are rare. What is their origin? How do they get their bearings in the dark? Benthic fishes have transparent bodies and small bead-like eyes; what can they see with such eyes in the total darkness?

Why are there fewer and fewer luminescent fishes as the depth increases? Is there perhaps some other source of light in those waters? We are still without an answer to the question.

It might be noted in passing that we are still not quite clear about the mechanism of marine bioluminescence. The luminescence of fishes remains a riddle, and we have not learned to imitate nature by artificially producing the substance that emits light in the process of oxydation.

How do the deep-sea animals and fishes hear? Here, again, we lack knowledge and can only guess. Body protuberances serve them as organs of hearing, in all likelihood.

It is generally thought that deep-water life is susceptible to a kind of caisson disease. Transition from pressures of hundreds of atmospheres to normal pressures is said to have a disastrous effect upon them, so that when they are brought to the surface and into an alien environment they perish.

Is there any truth in this supposition? These fantastic fishes are often actually dead when brought to the surface by the deep-water trawls, but perhaps the strangely high temperatures and excessive light are responsible, rather than change in atmospheric pressure alone. In other words they perish in the "troposphere" of the sea.

Research into the submarine world is being pursued with great vigour. With a regular fleet of research vessels criss-crossing the seas, instead of single ships as before, the remaining riddles shall be solved one by one.

We shall then have before us a detailed picture of what goes on in the realm of perpetual night. We shall know the secret of the pranks of Nature, which has created the fantastic and improbable creatures that we have been discussing. We shall find out how living organisms are able to adapt

themselves to an environment which should seemingly make life impossible.

There are things we do not know about the development of the organic world as well. Science is working on the reconstruction, bit by bit, of its history. Incidentally, the fact that scientists talk authoritatively about events that occurred millions and hundreds of millions of years ago, let alone thousands, testifies to the power of modern science.

The evolution of life on Earth is recorded in the Earth itself, including the mass of bottom sediments. It makes very difficult reading, and some of the pages are missing. Increasingly long probes of the ocean floor will give us material on the history of marine fauna. Geologists and palaeontologists will be furnished with new information on the Earth's early childhood, which will fill in the details of a balanced picture of its history, including the very first stages of the evolution of life upon it.

* * *

No less interesting than the ocean depths is the mysterious interior of the Earth.

We have learned to measure the ocean depths. We have learned to determine the composition of the ocean floor and to obtain probes from abyssal deeps. We have even glimpsed beneath the ocean floor.

A sharp detonation near the surface of the water sends a pulse of sound to the sea bottom, from which it is partially reflected. The sound penetrates farther, however, travelling through the layer of sediment, and reaching the crystalline rock, which reflects it back. The time interval between the two reflected signals, or echoes, is proportional to the thickness of the sedimentary deposits.

On land, the use of artificial seismic pulses has made it possible to penetrate several tens of kilometres into the terrestrial crust.

The outward solid shell was discovered to be composed of sedimentary and igneous rock, with granite underneath and basalt still farther down. That much has been established beyond any doubt. The same result has been obtained by different geophysical prospecting techniques. The next question

is, what is to be found beneath the crust? What is the nature of the core?

No definitive answer can be given to this question at present. The deep interior of our planet probably holds the greatest of its mysteries. The Earth's equatorial radius measures 6,378 kilometres, but we have more or less trustworthy information only about the superficial layer 30 to 40 kilometres thick.

In the ocean, no granite bed underlies the layer of sedimentary and igneous rock, as on the continents. It is particularly noteworthy that the crust is many times thicker on the continents, attaining a mean thickness of 50 kilometres, whereas in the ocean the floor and the next terrestrial layer, i.e., the mantle, are only four or five kilometres apart.

The substance of the mantle remains a riddle. We know no more than that it is different from the substance of the crust. The boundary between the crust and the mantle is known as the Mohorovičić discontinuity, after its discoverer, a Yugoslav scientist.

The mantle extends nearly 3,000 kilometres downward. Beyond that the composition of the Earth changes again: here begins the core, whose nature can only be guessed at.

Since no experimental data are available to support what is no more than speculation, penetration beyond the Moho will start an assault on the terrestrial core.

The power of modern engineering is unlimited. We have only to think back to the time when even a descent to the sea bottom was only a pipe-dream. Who might have thought that superdeep drilling would so soon be provided for in a realistic engineering project!

Having surmounted the water barrier, science will be nearing the so far inaccessible core. Instruments may be developed which will sound the Earth's interior as much as 6,000 kilometres down or even more.

Let us look at the facts. The continents and oceans have undergone changes and continue to change. The ocean, receding, continues to add land to the continental masses along the coasts. The process is not visible to the observer, of course, for geological time is measured by millenniums.

Dynamic processes are going on hundreds of kilometres down in the Earth's interior. Waves engendered by subterranean vibrations travel upward to the crust, causing displace-

ments. This activity continues despite the fact that our planet has existed for several thousand million years.

This need not be surprising, however, for the Moon, dead as is its appearance, is also showing signs of life: gas outbursts have been observed upon it recently by Soviet scientists and, later, by the Americans.

What accounts for all this activity, these constant commotions? What is the cause of volcanic eruptions? What is the origin of ore deposits? How did the oceans come into existence? We shall know the answers only when we break through the terrestrial crust.

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In the meantime, let us leave the Earth's interior and take a jaunt into the atmosphere.

The atmosphere is characterised by a complicated regime of its own. With the Earth beneath it, whatever occurs on land or water cannot but have repercussions in its lower layers. The upper layers, on the other hand, are under the continuous action of the Sun. The working of this entire solar-atmospheric machinery are still by no means clear. We do know, however, that the air currents, ionospheric storms, polar aurorae, and the weather itself are definitely determined by solar processes.

The exact nature of this mechanism is not fully understood. New and far-reaching interrelations must evidently be studied in this field. We must find an explanation for the origination and development of atmospheric perturbations; estimate with greater exactitude the heat and radiation balances and their fluctuations; and trace the transformations of solar energy reaching the atmosphere. We must make a minute study of the interaction of the upper and lower atmospheric layers over the northern and southern hemispheres, the ocean, and the atmosphere.

There is need for further refinement of the pattern of known air currents. It is necessary to take up the problem of climate improvement and weather control.

There are other gaps in our knowledge.

We have discovered relatively recently the occurrence of winds of hurricane velocity in the stratosphere, and a great deal more must be learned about them. No complete chart

of these aerial streams has been made so far, and we do not know what they imply in terms of energy.

Clouds, too, have been insufficiently studied, paradoxical though this may seem. How do clouds and cloud systems form? We have just begun getting data on this, with the help of artificial satellites, among other means.

There is a great deal of work ahead for all the observational and experimental equipment which is currently available to us.

While we need not undervalue past achievements, we must not conclude—as we continue to discover unknown supernovae and galaxies thousands of millions of light years away—that we have learned all there is to learn, be it only basically, about our own planet, and that whatever may remain unclear will very soon be cleared up.

The whole of our planet, with its biosphere and the adjacent zone of outer space, must pass through the researcher's laboratory.

We cannot afford to underestimate the difficulty of the task ahead. Many more voyages must be made by research ships, both surface and submarine, and many new hydrometeorological stations must be set up. Rockets and satellites shall have to be used to widen the scope of observation, of which our planet is the object.

It is to be hoped that the work of the International Geophysical Co-operation will continue for years to come, for it will take a great deal of joint effort on the part of scientists of various countries to acquire a detailed knowledge of our planet. Let us hope that the break-through into outer space will also make its contribution to the gigantic effort that is required to gain a fuller and fuller conception of the universe, from the atom all the way to the stars.

TREASURE-HOUSE FOR TOMORROW

Lest anyone should call the author to task for stressing "tomorrow" when there is so much to be done today, it should be recalled that any planning embraces at least the next few years and often the next few decades, while long-range plans may involve even centuries.

We are constrained, therefore, to look far ahead, referring our estimates to the end of the current century, to the mid-21st century, and even farther. To give an example, a great amount of effort is being directed to mastering the synthesis of the atomic nucleus, though the fruits of thermonuclear energetics, or its apogee, at any rate, will be enjoyed only by succeeding generations.

Scientists are currently working on numerous problems whose solution they may not live to see. Interstellar flights are not the only problem: one may mention those of synthetic foods, longevity, climate modification, conquest of the planets within the solar system, etc., etc. The foundation of any long-range plan must be laid today.

Let us attempt to take stock of the current needs of the world's population. Our requirements in regard to food, energy and raw materials run into truly astronomical figures. Here we are utterly unable to figure in terms of today.

All the resources of the Earth must be taken into account, and geological forecasting becomes one of the most important problems of science. Potential reserves are sought out in all branches of the economy. This quest is carried into the interior of the Earth, into the ocean depths, into the upper layers of the atmosphere and the near space; into those regions, in other words, which man has never probed before.

What is it that we may expect to find in those hitherto inaccessible regions?

To start with, we have begun to utilise the Earth's aerial envelope, that is, the atmosphere, which is a gas mixture, all of whose components can be of use.

Oxygen is used to accelerate the process of smelting in metallurgy. It is used wherever the natural conditions obtaining on the Earth have to be recreated on a smaller scale, as for instance, in the hermetically sealed cabin of an airplane or a spaceship, or in a submarine. Liquid oxygen is used for still other purposes.

Noble gases, i.e., neon, krypton, xenon, used in fluorescent lighting tubes, are a colour-rich medium of street advertising; and gas-filled daylight lamps can vie with sunlight.

Another raw material found in the atmosphere is nitrogen. It is indeed a life-giving element. A long line of vitally needed substances would not exist if it were not for nitrogen, fertilisers being the most important among them.

Liquid air, liquid oxygen and liquid helium are only a few examples of the raw materials obtained from the atmosphere. They make an unusual kind of raw material in that special caution must be exercised in their storing. Gas turned into liquid remains in that state only when vacuum protection is provided in the shape of containers with double vacuum-filled walls. These gases open up the astonishing realm of extreme low temperatures which holds out new prospects for engineering.

As to liquid air, that is needed as a deep-freeze agent. Helium, finally, in its liquid state remains a mystery to physicists in many respects. It is superfluid, to begin with, for its viscosity is not merely infinitesimal, but exactly zero. It is an ideal thermal conductor, in fact, it has the quality of thermal superconductivity. When it is used for cooling metals nearly to absolute zero they become superconductive.

Here, at the pole of cold, seemingly, another technical revolution is in preparation. Liquid helium will probably help to make pure, or, to be more exact, superpure metals, ideal conductors of electric current.

That will probably bring to fruition the hopes of developing superpowerful, supercompact accumulators of electric energy, supersensitive instruments and wireless equipment, miniature accelerators, and electronic computers.

It is hardly necessary to go on with the list. For it should also be recalled that the atmosphere is like the fairy-tale purse in which money reappeared as soon as any was taken out, and in the very same amount. This comparison became all the more justified after a discovery made in recent years.

We had known that the Sun is responsible for photosynthesis, a phenomenon which is still imperfectly understood, but a process so perfect that it is the envy of modern chemists. We had also known that the Sun determines the terrestrial climate. And it was only recently that scientists established the fact that sunbeams, in association with other cosmic radiation fluxes, ceaselessly create a regular stock of fuel above the Earth. Such a possibility had never been so much as suspected.

The atmosphere really does act like a suit of armour against the deadly breath of the cosmos, which, it appears, is capable of causing phenomena of vast proportions and turning the upper regions of the atmosphere into an arena for

metamorphoses truly astonishing from the standpoint of their aftereffects. It appears that electroconductive layers form in the upper region of the atmosphere, high above our planet. There are several such layers. They are unstable, their condition depending on the Sun. They provide us with immediate signals of any solar storms, for in such cases the layers disintegrate and long-distance wireless communication ceases.

For the sake of simplicity the stratified region of the atmosphere is referred to as the ionosphere. The ionosphere acts like a mirror, reflecting radio waves, and also like an accumulator of energy which is partially discharged at night, though at great heights the "energy purse" is never empty. The presence of atoms and molecules rearranged by the Sun means the constant presence of energy.

Should we try to estimate the amount of this energy, we would arrive at truly striking figures. The aggregate energy of our total coal, petroleum, shale and peat resources, with the forests and the energy furnished by the rivers and winds thrown in, would be less than the energy that can be supplied by the atmosphere.

One may ask whether that energy somewhere in the atmosphere, hundreds of kilometres above the Earth, might not be a mirage, something existing only on paper and in the calculations of scientists. Could it be as much of a mirage as the high temperature in the ionosphere? Temperatures of hundreds and thousands of degrees would not be felt in the ionosphere, because the gas is too rarefied and the particles too few in number, even though they travel at great speeds.

In order to study the energetics problems of the upper atmospheric regions rockets were sent up into the ionosphere, and released catalysts, such as nitric acid, for example. It was expected that the atoms of the dissociated, disintegrated molecules would join again and liberate the accumulated energy. A flash was expected to take place, therefore, and so it did: a great ball of fire appeared a hundred kilometres above the Earth, measuring several kilometres in diameter. Repeated experiments produced the same results: the luminescence of the air was brighter than the full Moon. One could observe from the Earth the bright star gradually expanding and night giving place to day.

It was thus confirmed that there was actually an accumulation of atomic gases in the upper region of the atmosphere.

Nitric oxyde converts atoms into molecules, and the accompanying prompt release of energy produces heat.

These artificial flashes up above the Earth added the chemosphere as a field for man's intellectual endeavour.

In addition to the ionosphere, which is a natural conflux of charged particles, i.e., a natural plasma, we now have the chemosphere, a source of chemical raw material which does not require mining as do minerals, is not radioactive as is nuclear fuel, and exists in unlimited quantities.

As soon as the chemosphere was discovered and as soon as it was established that atomic gases are produced in it, or fuel stockpiled, shall we say, as the result of solar activity, the idea was at once conceived of putting these gases to use in order to effect radical changes on the Earth.

This implies, of course, neither the surface of the Earth nor its interior. This atmospheric fuel must be utilised in the atmosphere itself. For we can capture the energy of the chemosphere only where it accumulates: we are as yet incapable of transporting atomic gases.

Near space has become accessible for modern technology. This includes the topmost layers of the atmosphere.

Atmospheric phenomena develop on a vast scale, and a vast amount of energy will be needed to exert an influence upon them. That explains why chemospheric energy will probably have to be used to regulate weather, to produce rain or wind, for example.

However, our stock of information on chemospheric energy is still too limited. In one way or another this energy reaches the troposphere, where the weather is determined, but we do not know just how this transfer is effected. The means of practical utilisation of this energy will be worked out as soon as the geophysicists come up with an answer to this question. Extreme caution will have to be exercised in any action, in order that our intrusion into this sphere may not result in disaster.

Airplane and rocket constructors are similarly interested in chemosphere fuel. A number of noteworthy proposals have been published in the press.

The ionosphere is now within easy reach of rockets, and airplanes capable of climbing to hitherto unattainable altitudes are in the blueprint stage. They will operate on this free fuel.

A prototype of the chemospheric engine is in existence. This is a ramjet engine, the simplest of propulsion systems. The air, upon entering the propulsion duct, is compressed, fuel is injected by the fuel injector, the exhaust gases are discharged through a nozzle, and an exhaust thrust is produced.

Capturing air in the chemosphere will do away with the need of fuel. One catalyst will be enough. Fuel injectors and atomisers will be dispensed with, as will flame holders, which, incidentally, it is very difficult to keep going at high velocities. The ramjet is especially useful for supersonic speeds.

Difficulties have been encountered in regard to the catalyst to be used. The catalyst, upon being discharged from the engine, would cause combustion of the air, thereby destroying the energy it contains, discharging this natural accumulator. This would do in an experimental airplane, but must be rejected for use in transport aviation.

A possible alternative is to use a solid and heatproof catalyst and to instal a grid of gilded tungsten in the propulsion duct. Gold has been found to be best as a catalyst.

Even this new alternative has proved unsatisfactory, however, for cosmic speeds, at any rate.

It would be very advantageous, of course, to use the free energy provided by the atmosphere for boosting satellite-launching rockets and interplanetary rockets.

The search goes on. Experimental models are constructed and tested. A chemospheric engine will be developed, as well as a chemospheric airplane, probably very unique in design.

A propulsion system using a standard type of fuel will be needed to get us up into the chemosphere. After which we shall want to come down, and here again a common type of fuel will be needed, rather than chemospheric fuel. It might seem logical to embody these various systems in one and to adapt one of the newest types of airplane, i.e., the vertical take-off and landing (VTOL) craft, for the purpose. Its circular wing would hold the turbojet and rocket engines, the fuel supply, and the passenger cabin. The cylindrical engine nacelles would be telescoped, the space in between forming the atomic ramjet engine ducts, with the catalyst grids inside.

A multiwinged pyramid-shaped VTOL craft has been designed, combining the features of a rocket and a ramjet

engine. As a rocket it will travel to the chemosphere, where it can supply itself with fuel free of charge. It will continue in the chemosphere after converting to an airplane while in flight, a propulsion duct within the pyramid serving for the passage of the air stream.

A chemospheric airplane will be capable of non-stop flight to any spot on the globe at speeds which will enable it to cross the Atlantic or cover the distance between Moscow and Mirny in Antarctica in ninety minutes.

* * *

And now let us turn our attention once more to that other ocean, the one that covers three-fourths of the world's surface.

Forty four elements have been counted in a single drop of sea water, among them widely known and widely scattered elements, and rare elements which have become both very important and very valuable. For technological needs, at any rate, these formerly scarcely familiar metals have now acquired a higher value than gold.

There is plenty of gold in the seas and oceans, by the by. Reckoned in negligible fractions of a gramme to a litre of sea water, it runs into thousands of millions of tons when related to the World Ocean. Dividing these thousands of millions by the number of people living on our planet we arrive at the impressive figure of more than three tons of gold for each of us.

Other metals are present in the ocean in still greater quantities. Thus, silver is estimated at 60 and thorium and molybdenum at 100 tons per capita of the world's population.

The list could be continued *ad infinitum.* It might be interesting to note that there is enough salt dissolved in the World Ocean to make a layer 45 metres thick if spread over the surface of the Earth.

The elements contained in the World Ocean are much more accessible than those which must be mined on land. No drill holes or mines are necessary. All that is needed—so it would seem—is to take the elements we want out of the solution of which they are the components.

Nevertheless, it is only recently that feasible methods of extracting all the chemical treasures contained in water have begun to materialise.

So far we have been extracting only common salt, mirabilite, magnesium, potassium, and bromine from the ocean; though it must be admitted that only one-thirtieth part of the total salt content is obtained from any given volume of sea water. Thus, the total annual yield of magnesium is only 300,000 tons, whereas its global supply is put at over $1{,}600 \times 10^{12}$ tons.*

There is hardly any need to cite other similarly striking figures to give an idea of the vast riches of the hydrosphere.

Incidentally, a very important consideration has been omitted in this exposition: only about half the elements contained in the Periodic Table (trans-uranium, unstable elements excepted) have been discovered in ocean water.

There is reason to believe that the rest of the elements are also present but have so far escaped detection. Modern refinements of chemical analysis techniques are evidently still powerless to detect them. The sensitivity of these techniques is continuously developing, however, so that these other elements, too, will be discovered sooner or later. Even if they turn out to be present in very small quantities, their global content in the World Ocean is bound to be substantial.

Chemical analysis of sea water has long since shown that the ocean can place practically inexhaustible resources at our disposal. There is enough common salt in it, for instance, to last mankind 1,500 million years.

The ocean contains still another type of raw material, whose future value simply cannot be overestimated. It would be wrong to regard sea water as a mere salt solution or a mere storage of numerous elements. Deuterium, which is a heavy isotope of hydrogen atoms, is invariably present in sea water. So is heavy water, which totals roughly 25 million million tons in the World Ocean as a whole.

The implications of this last figure will become apparent when plasma, once controlled, will start working for mankind. Sea water will provide us with the raw material needed for controlled thermonuclear reactions. There is enough of this raw material to last us many thousands of years to come.

Heavy water is naturally associated with common water. There is very little of it, and separating it from common water is quite a difficult task. Modern technique, however,

* 1,600 trillion (Am.) or billion (Eng.) tons.

is capable of achieving tasks of this nature, and that explains the current conviction that the seas and oceans are an immensely rich source of nuclear raw material. For deuterium is present in dissolved form, in ultramicroscopic amounts, in every single drop of water.

It is a matter of fact that conditions vary greatly and that extremely diverse transformations occur in nature. One wonders whether nature may not have stocked a supply of heavy hydrogen somewhere or other. Heavy water is heavier than common water, as its name implies. It will be recalled that deeps exist in the ocean, where the currents are slow and there is no pronounced mixing.

Subterranean pockets are known to exist, which accumulate fresh water. Might not there be places in the ocean where deuterium-filled pockets have accumulated under pressure, pools of heavy water in common water? The hypothesis exists, and if it is substantiated, then highly valuable nuclear fuel could simply be pumped to the surface out of the deep.

In the future the ocean will supply raw materials to the chemical industry and thermal power plants.

A few words now about the ocean's mineral resources.

The subterranean occurrence of minerals, whether on dry land or under the ocean floor, is doubtlessly subject to the same laws. Geologically, the ocean floor is much the same as dry land. Simple logic, even simple analogy seem to justify the conclusion that the ocean floor, which is the same upper layer, only covered by water, must contain minerals, ores, petroleum, and gas.

This conclusion finds support in the fact that petroleum derricks are going up farther and farther out to sea and that fields of lava, which is a most valuable fusion, are even more extensive on the ocean floor than on islands and continents. The world's most active seismic zone lies on the ocean floor along the coasts of the Pacific Ocean.

The ocean floor is thus to become a new field for geological research.

While in time geologists will penetrate into the deep interior of the ocean floor, our immediate problem is the ocean itself, whose resources have yet to be studied and evaluated. One figure, however, must be cited: according to geologists the petroleum deposits of the continental shelf alone are equal to one-third of the prospected deposits on dry land.

Petroleum is already being recovered from the continental shelf, which, however, is expected to yield much more than just petroleum. The ocean beaches are covered with what fully deserves to be called gold-bearing sand, for it contains such quantities of zirconium and hafnium that the Australian coast alone can satisfy the demand of all the capitalist countries. Rare elements are to be found on other coasts as well. The sands, then, are by no means to be overlooked as a source of riches.

Sea-bottom photography at great depths, trawls and dredges furnish incontrovertible evidence that the floor of most seas and oceans is fairly strewn with ferromanganese concretions. No explanation has so far been found of the origin of these nodules of pure ore containing up to 15 per cent iron and 25 per cent manganese.

Nickel, cobalt and copper are also present in this ore in quantities of 0.5 per cent, as well as some other metals.

This constitutes a regular treasure, and a treasure of gigantic proportions at that. The global figure of concretions in the World Ocean is apparently not less than 350,000 million tons. So great a treasure must not stay buried on the ocean bottom: extraction of these concretions must have top priority in any programme for tapping the ocean's resources.

A word about another type of submarine riches, before we leave the sea floor. Scientists have discovered that vast areas of the sea floor are covered with deposits of red clay, which contains aluminium and copper in quantities running into hundreds of thousands of millions of tons.

Bottom pockets of radium or uranium are also most likely to be discovered. A deep-sea fish with such high radioactivity was once caught, that it could not be eaten; could it have been living in the vicinity of a uranium deposit, by any chance?

Now that we have dealt with the resources of the ocean floor, let us turn to those of the water column proper.

The food resources of the World Ocean are put at 40,000 million tons annually, or four times those on dry land. The sea could be made to yield between 50 and 60 million tons of fish annually without detriment to the renewal of fish stock.

Sea food is ordinarily consumed by populations living along the coasts. Plankton is entirely unknown as a food,

despite the recent proof given by Dr. Bombard that it can be used as such. Incidentally, it is the standard diet of the whale, and the whale is the largest mammal on earth, larger than the elephant, and reaches maturity in the space of only two years.

If it should prove possible to feed plankton to animals and to use it for human food, we would be able to harvest 360 million tons of it annually.

As to seaweeds, the microscopic chlorella, which gained fame by having been taken for a spin in outer space, could set a record by yielding a harvest of 43 tons per one hectare, which is quite within its possibilities. Moreover, it has four times the protein content of wheat grains. So that here we may reckon on the availability of hundreds of thousands of tons of food, animal feed, and raw material resources.

We have seen that the ocean can provide us with food and raw material. It can also provide us with energy.

The sea is continuously in motion. The ebb and flow of the tides, which are caused by cosmic forces, occur with unfailing regularity. Vast, indeed, must be the power that sets the sea in motion twice a day.

The thousands of millions of kilowatts generated by tidal waves are completely wasted. So is the energy of wind waves.

Nor has the natural heat mechanism of the ocean been put to use.

The heat content pattern of the ocean is uneven, temperature differences in the warm seas being very marked. While the upper layer is heated to high temperatures by the Sun, the temperature drops with depth. This vertical temperature gradient can be put to work.

The warm water would evaporate some kind of quick-boiling liquid or other. This would be possible only under low pressures, to be sure. However, there would be no difficulty in creating a vacuum within the evaporator, nor would it be difficult to convert the vapour back into a liquid by forcing cold water up from the depth. The vapour, or steam, would be used to power the turbines.

A thermocouple could also generate a current if its junctions were placed one in a cold, the other in a heated layer of water.

Tidal power stations will utilise the treme
dous energy generated by the ocean tid
now going to waste

Geothermal power plants could be built both in southern and northern waters, for adjacent cold and hot layers are to be found in both. The World Ocean will be able to supply unlimited amounts of energy once tidal, wave, and thermal power stations are constructed.

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We have seemingly surveyed everything that the ocean can give us, even taking a peek into that part of the terrestrial crust that lies under the ocean floor. It remains for us to complete our reconnaissance of the future by investigating the bowels of the Earth.

In their quest of useful minerals men have worked through a vast amount of rock, but the riches of the upper storey of the underground storehouse are far from depletion. New discoveries are made at a sufficiently rapid rate, especially now that new prospecting techniques have been developed and geological prospecting is increasingly based on scientific forecasts, rather than on guesswork.

Examples of this are plentiful: one has only to look at the petroleum of the Tatar Republic and Siberia, the diamonds of Yakutia, the newly discovered gas fields and deposits of iron ores and various valuable metals. Unfortunately, we have invariably squandered what nature has been storing away over millions of years, wasting it irretrievably, and at a rapidly increasing rate.

Reports are already abroad that we have petroleum to last us only another forty years. It has already been estimated that our global supply of fuel of all kinds will be depleted by the end of the century. The deposits of metal ores will also become exhausted before long. Sooner or later everything that can be discovered near the surface of the Earth will have been discovered. We shall then be forced to reach into the depths of the Earth's interior. There is every reason, therefore, to call the geology of the future a "geology of the depths".

Supposing that we succeed in going several kilometres and, later, several tens of kilometres farther down into the interior: what can we expect that to give us? The answer is that here we are dealing with the unknown; for no estimate, however rough, is available of the treasures that

we might find within the crust as a whole and in the subcrustal layer.

There is no use trying to guess exactly what metals and ores we may be able to extract at great depths. We shall, however, mention one type of rock which, according to Dmitry Shcherbakov, member of the U.S.S.R. Academy of Sciences, is exceptionally valuable and bound to become a source of metallurgical raw material. We are speaking of basalt.

Basalt is practically one-half silicon, one-sixth aluminium, and contains quite a substantial amount of calcium, iron, magnesium and titanium. It contains some rare elements and precious metals. It could be used as building material and for stone castings of extreme stability, which could in certain cases replace metal castings.

Basalt is perhaps the commonest type of rock on our planet, underlying the granitic continental base and forming the floor of the ocean. The supplies of this rock are so vast that they will never be exhausted no matter how much of it we might extract.

Under the basalt, magma is to be found in the terrestrial crust. It either bursts to the surface through volcano craters or else finds its way into empty pockets and forms so-called magma chambers.

We are interested in magma as a source of raw material. While we have so far found no way of conquering volcanoes and putting an end to the tremendous damage that they cause, the idea has been conceived of producing artificial eruptions of a tame variety by sinking deep bore-holes to tap known magma chambers, filling these with water and pressing the magma up to the surface with the aid of the steam thus produced. Our industry would thus obtain another type of raw material in the form of a melt containing many useful metals.

In time we shall tap the heat of magma chambers at depths of five and even ten kilometres, and the current generated by volcanic power plants will flow into a single electrical grid.

Geological discoveries, however, may be expected in the seemingly thoroughly explored upper strata of dry land, too. An example will show how our notions regarding the resources of the Earth's upper layers have expanded.

There are spots to be found on every continent, where numerous hot springs spout boiling water and gases. Besides

the heat generated deep down in the Earth a great amount of substances of all kinds is cast up on the surface through these vents, very much in the manner of a syphon drawing on a gigantic reservoir, a subterranean sea filled with a hot solution. Cases are known where such syphons have operated with unabated force over tens of thousands of years.

Until quite lately, however, we did not realise what uses these underground waters could be put to. We are accustomed to refer to them as "thermal" waters, for they are heated to hundreds of degrees, so that a mixture of steam and water, rather than just water, erupts to the surface.

Thus the Earth's interior is ready to furnish steam for turbines and hot water for heating and other utilities and household purposes, as well as for greenhouse use. Properly managed, such a source could satisfy the needs of a city.

One might be inclined to suppose that this would be possible only where existing geysers have replaced extinct volcanoes. In Italy and Iceland, for instance, geothermal plants have so far been built only in such localities. Hot subterranean water is also used in Japan, America and New Zealand.

As a matter of fact, however, regular lakes, even seas of thermal waters are known to exist underground in other, non-seismic regions on all the continents.

So far as the Soviet Union is concerned, considerably more than half its territory could switch to the use of subterranean heat. The West Siberia subterranean basin happens to be the largest in the world, covering an area of three million square kilometres. Fifty or more sizeable towns could dispense with fuel if these thermal waters came to be tapped.

It is worth noting that this subterranean heat costs less to use than any other kind, so that it would mean price reductions on greenhouse fruit and vegetables. Besides, chemical factories would naturally be set up in the vicinity of the rural power plants in order to produce millions of tons of valuable raw materials now lying idle.

In Germany, some thirty years ago, there came out a book* devoted to the consideration of future power resources on a world-wide scale and taking up one after the other all

* H. Günther, *In hundert Jahren, Die künstige Energieversorgung der Welt*, Stuttgart, 1933.

the various kinds of energy that man may be using a century hence.

The author dealt with wind power, the ebb and flow of tides, the geothermics of land and sea; and also with the potentialities of nuclear power–in the distant future, for the energy content of the atomic nucleus would be released, in the opinion of the author, only by the generations to come. As it actually turned out, however, the conquest of the atom was achieved in a much shorter time.

Moreover, the author's time-table was upset: it was precisely the latent energy of the atom, rather than of all the other possible sources, that was the first to be released.

Construction of the first large power plants to use the energy of the ocean is just beginning. Thermal heat is just being brought into regular use. Wind power had so far been used on an inconsiderable scale. Atomic plants with an output of hundreds of thousands of kilowatts, on the contrary, are already going up. Ships, including surface craft and submarines, are already equipped with atomic reactors; airplanes and spacecraft are next on the list.

The urgent problem, however, is to find resources to satisfy the ever-growing consumption of power. If we stop to think that a one per cent increase of industrial production calls for a two to three per cent increase in power output, we shall realise that our power resources must be steadily developed, and that the problem of power must be assigned top priority.

This explains the wide scope of the current research programme, which covers all the known sources of energy in the world. Science and engineering have set themselves the task of finding new ways to harness these sources.

Our attention is focused primarily on the Sun. Only a negligible fraction of solar radiation reaches the Earth, yet even that is nearly forty thousand times more than the total amount of energy we currently consume. Quite naturally, therefore, engineers have taken up the problem of developing solar installations, starting with those designed to produce heat, and lately turning their attention to those that can generate electric current.

Abram Joffe, member of the Soviet Academy of Sciences, considered the shifting sand dunes of the desert particularly suitable for locating superpower stations.

If a network of semiconductor batteries were set up over the world's desert areas, we would be guaranteed a total of 1.5×10^{12} kilowatts.* Helioenergetics, still in its infancy, has much to give us in the form of power plants in deserts, on mountain slopes, in the tropics, and on man-made islands in the ocean.

Semiconductor thermo- and photocells are of especial interest for trans-atmospheric helioenergetics, for outside the Earth's atmosphere the sunbeams are not weakened by traversing the Earth's gaseous envelope. In conditions of imponderability gigantic capturing surfaces are feasible, making for a high concentration of energy. It would probably be possible in this way to utilise a much larger share of the heat and light radiated by the Sun.

The Moon, if saturated with semiconductor photocells, could produce electric power measured in tens of billions (Am.–trillions) of kilowatts. This gives an idea of the possible scope of cosmic helioenergetics.

The proposition is striking but by no means far-fetched. It would be impossible to convert the Moon into one great power plant, to be sure; nor would that be necessary, for solar installations could be set up on artificial satellites orbiting the Earth. Still, solar radiation will be used by lunar settlements as a source of energy for their own economies.

In time, when a trans-atmospheric industry will have been developed, the Moon and other space stations will provide it with energy via directed radio beams. However, the Earth, too, will be able to call on them, if need arises, for the required amount of kilowatts, even if it will not run into billions.

Vast quantities of power will some day be captured both on our sunlit Earth and on the Moon, as also on the man-made garland of semiconductor batteries girdling our planet, and eventually perhaps even on the Sun.

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After our survey of the cosmos let us take another look at the Earth. To begin with, many of our rivers remain unharnessed. All the rivers of the world put together could pro-

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* 1.5 trillion (Am.) or billion (Eng.) kilowatts.

duce annually a thousand times more power than is currently consumed. While gigantic hydraulic power plants are being designed or built, the remaining resources are still very extensive.

Wind power has remained practically untapped, yet it could also make a contribution to the global energy balance, and a substantial one at that. Wind-driven electric plants on land alone could yield as much energy as we get from the Sun, but they could be built upon islands in the oceans as well.

Nevertheless, vast as the natural power resources may be in the ocean, on land, and underground, they are less great than the atom. We shall reproduce stellar matter, and plasma, brought under control, will supply us with unlimited energy. It might even supplant all our other energy sources. At any rate we shall stop burning such valuable chemical raw materials as petroleum and coal.

Our paramount interest in thermonuclear synthesis may need a word of explanation. The terrestrial crust is known to contain 16 million tons of nuclear fuel, i.e., uranium and thorium. A gramme of this fuel yields millions of times more energy than a gramme of coal. In terms of kilowatt-hours the accumulated energy of a split nucleus would be represented by the figure 5 followed by seventeen zeros; or, taking the annual global power consumption as one unit, it would equal 10,000 million such units.

The figure is considerable, of course, from the standpoint of the immediate and proximate future, but insufficient in the long-range view. For energy requirements are not limited to industrial production, transport, agriculture, or household uses.

We need energy to help us penetrate the Earth's interior, the ocean deeps, and outer space. We need it to rearrange things on our planet and carry out various stupendous engineering projects, both those that exist today and those that will be worked out in the future.

Perhaps it will fall to our lot, after all, to achieve the inspiring task of establishing contact with our cosmic neighbours. So far as interstellar flights are concerned, these are now viewed as within the reach of our rather proximate descendants, who will learn to solve problems of planetary

dimensions, to which we shall have made our contribution. To do that it is necessary first to solve the problem of energy.

The prospects of atomic power development are visibly growing broader and broader. Thermonuclear synthesis has been taken out of the field of theory. Control of plasma will open up possibilities which it is no exaggeration to call limitless.

We should have enough raw materials for nuclear synthesis to last us 25 million years even if the current average annual consumption of 10,000 kwh rose to a million or the world's population, which now stands at 3,000 million, increased to 100,000 million.

The food problem is equally important. So far, man has had to maintain himself essentially with the produce of the Earth. The food chain begins with plants, both on land and in the ocean, where the process of photosynthesis is induced by solar radiation. On land, plants constitute human food and animal fodder. Seaweeds in the uppermost water layer form the initial stage in the food chain of marine life. Marine plants, however, are still practically unexploited as a source of human food.

Certain neo-Malthusian theories hold that the world is headed for overpopulation and that starvation is therefore the fate in store for mankind. Estimates of potential food resources, compiled by Konstantin Malin, a Soviet economist, may serve as an effective refutal of these theories.

Not all species of plants are fit for human consumption or feeding animals. Supposing, however, that solar energy, now distributed among all plants, were to be consumed exclusively by the edible species: the latter would then be able to sustain a human population of around 60,000 million. And if all forms of marine fauna were fit for food they could support a population of practically 300,000 million.

These estimates are, of course, on the fringe of fantasy. They refer to ceiling availability.

Equally fantastic, however, though fully feasible in the not so distant future, is the production of foods which stand in no need of the Sun. Photochemistry is bound to give place to the chemistry of synthetic proteins. A variety of foods will be manufactured by purely laboratory techniques without the participation of sunlight. The Sun will be supplanted by a thermonuclear sun.

We have still a long, long road to travel before we are able to serve synthetic meals. Our present interest, therefore, is focused on our natural food resources. There are many of these, and many are already being used. It is pertinent to wonder what more can be gotten in this more or less familiar field.

To begin with, consider the problem of yield stimulation. Only biological stimulators are capable, provided their use becomes sufficiently general, of increasing the yield of certain vegetables by 25 and even as much as 50 per cent. Pest control alone would make it possible to double the global agricultural output. Intensive use of nitrogen fertilisers could by itself bring about a great increase in food production.

Turning to figures again, we must refer to the estimates of those American writers who have gone into the problem of food availabilities on our planet.

We find that only ten per cent of the total land area is currently under cultivation, excluding Antarctica. Even if we were to exclude mountains, deserts, permafrost areas, glaciers, swamps, tropical jungles, forests, and other uninhabited regions, there would still remain extensive areas suitable for agriculture.

Some further elimination is indicated in the interests of greater exactitude. Thus, we shall eliminate regions where precipitation is insufficient, or sufficient but irregular. Also those regions which are naturally humid but deficient in warmth, and those whose topography is unsuitable for agriculture. Finally, we shall eliminate areas with sufficient precipitations and heat, and suitable for cultivation, but insufficiently fertile.

In the end, after all our eliminations, we find that only seven per cent of dry land would satisfy the requirements in regard to precipitation, heat, topography, and fertility.

The result leaves little room for complacency. However, it is up to us to introduce the required adjustments into our geographic environment. Turgenev, the celebrated Russian novelist, said that nature is a workshop, not a temple, and we are the workers.

Where there is insufficient precipitation we must turn to irrigation and sprinkling systems; and make changes in the geography of rivers and seas.

Where there is not enough heat we shall have to wait until the development of power resources makes it possible to control weather and climate: having learned how to govern air and ocean currents, we could use them to redistribute solar heat without prejudice to the general balance in nature.

Where the soil is unsuitable for agriculture we can learn to do without it by feeding nutrient solutions direct to plant roots and using gravel and limestone in lieu of soil; for hydroponics are already used in agriculture.

Agriculture can be extended, if needed, northward or southward, at our discretion, to former desert, swamp or jungle areas, and to sloping ground in the hills. There is nothing inconceivable about farms in underground caves, on man-made islands in the ocean, in the vicinity of the Arctic Circle, or in Antarctica. Fruit and vegetable gardens in outer space, long-distance rockets, space stations, or lunar settlements, for instance, are today a subject of matter-of-fact discussion.

No reference, incidentally, has so far been made to plant and animal selection or to any transformation of plant life: we have only approached the mystery of heredity and barely begun to exercise influence over the inheritance of specific characteristics.

It follows that the American estimates should be revised: seventy per cent, if not more, will be a more accurate evaluation than the seven per cent that they suggest as the potential global cultivable area that could support twenty-two times the number of people living on our planet today, and even more if the possibility of increasing yields is taken into consideration.

These figures are based on current scientific findings. Some of them are taken from Prof. John Bernal's *World Without War*. The work of the American economists Frank A. Pearson and Floyd A. Harper, whose estimates we have quoted, is entitled *The World's Hunger*. War and abundance, as we see, are incompatible concepts.

We are firmly convinced that wars of destruction will be banished. We firmly believe that a happy future is in store for our world. Our planet is incredibly rich, and once we learn to use its riches wisely we need never be afraid of running out of food, or raw materials, or energy.

EXPLORING THE UNKNOWN

Before development can be undertaken in any sphere, be it the ocean deeps, the Earth's interior, the upper layers of the atmosphere, or the space that surrounds our planet, the particular sphere selected must be explored; and that, in turn, depends on the availability of technical means with which we can penetrate into it.

Technical means of another kind will be needed when the time comes to establish ourselves firmly in those new realms which man is intent on penetrating.

One of the tasks before us is to explore and develop the World Ocean, from top to bottom; special devices will be needed to do this, and it is important to realise that the different levels of the ocean will call for different types of devices.

While the mean depth of the World Ocean is four kilometres and that of the continental shelf not over 300 metres, deeps or trenches eleven kilometres down are known to exist.

The water mass is generally considered to be composed of the upper, intermediate, and lower layers, and it stands to reason that the same type of equipment cannot be used in all three.

In considering equipment suitable for shallow-water operations it was found that past experience was of no value. The idea of a diving suit, which dates back to remote antiquity, proved useless despite any changes that might be made. It was essential to do away with the air tube, which was liable to tangle or break and tethered the diver, limiting him in his movements. A way out of the dilemma was offered by the aqualung.

Its introduction afforded excellent opportunities for exploring depths of not over a hundred metres. It was responsible for man's first venture into the ocean, trivial though these few tens of metres may seem as compared with the remaining kilometres.

The ichtyologist, botanist, and geologist use the aqualung in observing their respective spheres: the life of fishes, the marine flora, and the coastal shallows.

It is useful to construction workers on underwater projects, for inspection and repair work on ship bottoms, and for salvaging wrecks.

Equipped with an aqualung, a diver can stay below the surface for not over an hour. Quite recently a team of researchers lived for a month on the bottom of the sea, at a depth, it is true, of only about fifteen metres, for the purpose of testing the world's first submarine dwelling, constructed by the French oceanographer Jacques-Yves Cousteau.

That was a fruitful experiment and its chief value lay in the fact that it proved that man can live and work in shallow waters. Small submarines for underwater tourism, filming and observation over the continental shelf have now been constructed. They will be indispensable for getting at marine resources.

They will be used for prospecting seaweed meadows and selecting locations for future plantations; in the search of useful plants, and food fishes and animals; and for geological exploration of the coasts.

These midget submarines are built of durable synthetic materials, including glass fibre, and equipped with electric or diesel-electric engines. New synthetic materials for hull construction and miniature atomic batteries will eventually be used. Lightweight diving suits will enable crew members to work outside under water.

Submarines equipped with wheels or caterpillar tracks and mowing devices will be used for harvesting seaweed crops. This type of ship may have a twin hull with the mowing mechanism between the two sections.

There is much to be done before equipment for submarine plantations is developed with the maximum use of automation. Theoretically, however, a submarine agricultural fleet is perfectly feasible, and in the immediate future, as a matter of fact.

Shallow-water equipment will not do for the intermediate layers. One hundred metres is as far down as one can go with an aqualung. A midget touring submarine is not suitable for cruising all the way up and down the continental shelf. The older types of equipment, such as the heavy diving suit and even the navy type submarine, are equally unfit for the purpose.

An initial experiment was made, to be sure, when a Soviet Navy submarine, withdrawn from service in 1957 and christened *Severyanka,* was disarmed and provided with an observation port and suitable equipment. It was probably the first

submarine ever to be made available to scientists. New craft for intermediate depths exploration are currently being developed.

Jacques-Yves Cousteau has named one type of these the *Soucoupe*, or diving saucer. Its spun steel hull accommodates a crew of two, in prone position, who can carry on observations, take pictures, obtain water and bottom samples, and pick up things with a prehensile arm.

If an aqualung diver, swimming frog-like under fathoms of water, presents a strange sight, the diving saucer moving through a jungle of seaweeds along the continental slope with schools of curious fish flocking to the lighted observation ports presents a sight still more incongruous.

The line where the upper and intermediate water layers merge is the limit for modern submarines. In the future, however, submarines built specially for the oceanographic fleets will be able to dive much deeper.

One such vessel is being designed by Soviet engineers. It will provide as much comfort for its team of scientists as was enjoyed by those on board Jules Verne's *Nautilus.*

Professor Aronax, the *Nautilus*'s involuntary passenger, gazed at the submarine world through a large plate-glass window. The new Soviet vessel, provisionally known as *Sever-2*, will be equipped with two similar windows.

Sunlight penetrates with difficulty to the limits of the continental shelf. The vessel, which will be able to attain a depth of two kilometres, will be equipped with powerful searchlights to dispel the perpetual darkness.

It will be equipped with all manner of devices, including cameras—ordinary, film and TV; hydrophones; sonar; and various instruments and handling devices; so that it will be able to make a pictorial record of deep-sea life, monitor the sounds of the sea, spot schools of fish, take various samples, and collect interesting finds.

Its oblong hull will be of steel and plastic glass construction. It will have a cruising radius of some 90 kilometres.

Among the other types of deep-sea craft that are to follow is the submarine helicopter, or mesoscaph, which, as the latter name implies, will operate at depths of not over two kilometres. The word helicopter is used here in its proper technical sense. The spheroid hull of the mesoscaph will be equipped with a large rotor providing a lowering rather than

a lifting force, which will drive the craft downward. As soon as the rotor stops the craft will rise to the surface. Small propellers are provided to drive it forward.

Compared with the first deep submergence, which set a record of roughly one kilometre, the mesoscaph will assure mastery over moderate depths in the fullest sense of the word.

Deep-diving vessels lowered from a ship by wire rope are still in use. A modern diving chamber of steel, ringed with observation ports, can also attain moderate depths. Soviet diving chambers reach the floor of the Barents Sea 600 metres down.

The device, which affords comfort to its occupants, has the one drawback that it lacks mobility and the observer is deprived of choice: he can observe only what happens to be in his field of vision.

Researchers in a mesoscaph, on the other hand–and this holds true of any submarine turned into a research vessel–can move freely in all directions, and are therefore in a position to observe the behaviour of marine life, explore the topography of the ocean floor, keep an eye on their trawl, etc.

An important feature of the mesoscaph is the possibility of observation in all directions, rather than on one plane only, inasmuch as its spherical cabin is constructed of transparent plastic; so that seen from outside the mesoscaph gives the impression of a man suspended in the ocean depths within a bubble of air.

Penetration to still greater depths, however, will require another type of device. Here we must turn to the submarine once more, but it will differ from the modern submarine in regard to both material and hull design.

It might seem that the breaking strength of modern materials is adequate as it is and that it is impossible to increase it much more. Theoretically, on the other hand, the laws of the interaction of intermolecular forces indicate that metals could resist loads at least a hundred times greater.

Methods of obtaining superhard metals are currently being developed and undergoing laboratory tests. At present we have succeeded in making only a very fine thread out of a definitely superstrong metal. If this sort of material is made available to shipbuilders the submarines of the future will

need no particular intricacies of design to enable them to submerge to a depth of six kilometres.

In the meantime, however, special features of design must be resorted to. In line with the principle of using a wedge to drive out a wedge it has been suggested that the exterior pressure of water might be counteracted by the resistance of some lighter fluid, such as benzine, perhaps.

In such case the benzine would be pumped inside a double plating. This would effectively prevent any buckling or torsion of the hull under the pressure of the column of water. Liquids are practically non-compressible, and here the benzine or silicon would bear the brunt of the pressure. Light exterior plating could then be used in order to reduce the weight of the submarine.

In the foreseeable future, then, we may see submarines, large and small, designed for the upper, intermediate and lower depths, penetrating hitherto inaccessible reaches of the ocean. Some will be designed for exploration work, others for fishing, still others will serve as bases for geologists engaged in development operations on the ocean floor. Their joint efforts will make the resources of the ocean available to mankind.

Six kilometres down is not the limit, of course, for there are deeps and trenches in the World Ocean still farther down. Their aggregate area is substantial, and they are of great interest to science right now from the standpoint of practical utilisation in the future.

It is precisely along these strings of deeps that the most troublesome areas of the Earth's crust are situated and earthquakes are most frequent. A great many submarine volcanoes are to be found here, some of them still active. The various processes going on in deeps as much as eleven kilometres down are reflected on the surface of the ocean and even on dry land.

There have been frequent disasters which have left an indelible memory, such as the tragedy in Chile whose echoes reached the shores of Asia. Submarine volcanic eruptions and earthquakes centring under the ocean produce destructive tsunamis. A study of the geological regime of the deeps may lead to prediction of these destructive upheavals of the Earth's

Submarines designed for the upper, intermediate and lower depths will range over the oceans

crust, and to control over them, fantastic though this may sound at present.

There is a possibility that ore and even pure metal deposits are associated with these disaster spots. Who knows but that submarine mines will be worked in the vicinity of such volcanoes once they are subdued.

There is quite a difference, for all that, between six kilometres below the surface and eleven. At eleven, the pressure of the water is nearly double; on the floor of the Mariana Trench, one of the world's deepest, it is more than one thousand atmospheres. No metal now available or which may be produced in the near future could withstand so great a pressure, unless, of course, at the expense of excessive weight and size of a vessel.

Nevertheless, a benzine-filled thin-walled plastic float took a small steel sphere, with men in it, to a depth of nearly eleven kilometres, without mishap. These several elements: the float, the watertight gondola with which it was connected, the engine and propeller, the ballast and guide rope, may well be regarded as the marine, or rather submarine equivalent of an airship.

This device inaugurated the exploration of the lower depths. Using such a device, the bathyscaph *Trieste,* Jacques Piccard and Don Walsh set a world record in 1960 in a dive of nearly eleven kilometres to the bottom of the Mariana Trench. That is as far down as one can go at present, for there is no known trench deeper than the Mariana.

Bathyscaphs are now being designed or constructed in a number of countries. The Soviet Union, too, is initiating a programme of deep-diving craft.

Looking much farther ahead, scientists are discussing a twin-hull bathyscaph, a bathyscaph with a multisection hull, and a carrier bathyscaph, so to speak, for work at great depths.

The carrier bathyscaph will be invaluable to scientists who study marine life at great depths and explore the ocean floor in an effort to clear up our planet's past history; and also to those who will be engaged in development work on the ocean floor, from the continental shelf to trenches many kilometres deep.

In addition to floating laboratories, permanent observation stations will be set up at various depths, just as they have

been set up in the Arctic, in Antarctica, in the mountains, and other inaccessible spots, and just as they will be set up in outer space: on manned satellites, on the Moon, and in the vicinity of the planets.

Submarine dwellings will be set up on the sea floor both on the continental shelf and farther out in the ocean. They will have double walls, like the hull of a deep-diving submarine, and compartments also similar to those of a submarine; there will be a lock-chamber for coming and going, laboratories, living quarters, and storerooms. Various vessels will be placed at the disposal of these submarine dwellings, such as small craft with automatic devices for gathering concretion specimens and equipment for fishing, and submarine "jeeps" equipped with boring drills for obtaining samples of bottom material and vertical sections of sediment.

A few words should be said, in closing, regarding underwater communication: submarine station to station, station to ship, and station to surface. Here, radio waves will be replaced by sound.

In case it may be doubted that sound will carry over long distances inasmuch as acoustical wave energy is soon scattered, and that long-distance communication is therefore hardly feasible, we must say that we propose to discuss communication over extreme rather than merely long distances: for sound-conducting layers have been discovered deep under water. Sound can travel over thousands of kilometres under water just as radio waves travel through the atmosphere.

As to "going outdoors": this will require a diving suit of extra-strong material constructed specially for use at great depths. It must assure the wearer reliable protection against the huge pressure, while allowing freedom of movement and action. Deep-divers will probably be equipped with personal miniature motors and propellers. Such outfits will be useful to marine geologists, whose sole equipment at present is the aqualung.

* * *

Powerful forces are available to man in this, the second half of the 20th century.

He has millions and thousands of millions of kilowatts of electric energy at his disposal. He is able to create pressures of up to half a million atmospheres, and even up to five

million in the brief instant of an explosion. He controls powerful magnetic and electric fields, and creates lightning flashes that can vie with those of nature. He obtains temperatures that are not to be found even in the interior of the Sun; and plasma, or stellar material, has already been produced in his laboratories. He calls in chemistry to intrude into natural processes and rearrange molecular and atomic patterns to suit his needs.

The powerful technical resources now available to mankind are directed to increasing our mastery over nature. Temperature and pressure aid us in reconstructing substances; gas discharges and superpowerful magnetic fields yield high-temperature plasma; and control of the latter leads to the mastery of thermonuclear synthesis.

Even if we refrain from attempts to look that far ahead, however, to the time, that is, when an abundance of energy will surpass anything we may conceive today, we cannot doubt that new technical equipment will lead to new developments in the scientific and practical fields within the next few years. Our all-out effort to penetrate the Earth's interior is an illustrative example.

We have been inexorably driven to realise the necessity of driving deeper into the Earth in our quest of its riches. Yet every metre gained, to say nothing of every dozen metres, should be regarded as a hard-won victory. It is perfectly understandable, therefore, that the geophysicists of many lands should have resolved that the time has come to carry out one of the boldest schemes ever conceived by man.

This is the Upper Mantle Project, which proposes to use all known scientific methods to study the subcrustal substance, including drilling beyond the depths attained thus far; a vast enterprise which should immediately furnish explicit answers to numerous questions. The Upper Mantle Project is rightly compared with schemes designed to conquer the near space.

The first sample of the Earth's deep interior will enable us to verify our guesses and assumptions concerning the nature of the mysterious substance of which it is composed. We shall then be able to form a more accurate conception of the Earth's core, even if we fail to reach it.

In the field of geophysics the event will be of the same magnitude as would the return of the first cosmonauts with

a lunar fragment in the field of astronomy. By drilling to great depths we shall obtain more information on the structure and origin of our planet and the sequence of geological periods.

Besides serving the interests of pure science, a study of the Earth's interior will reveal the distribution of the elements and thus facilitate their recovery.

An attempt to penetrate to the mantle has already begun. This is an American project which attacks the problem in an oblique way by drilling in the ocean, where the crust is thinnest, rather than on land.

The project required the stationing of a floating drilling rig out at sea. A depth of nearly four kilometres seemingly precluded anchoring the derrick, yet it was necessary to hold the four-kilometre-long system of drill-pipe in a rigid position. The problem was solved by using locators to keep a continuous check on the vessel's position and the propellers to maintain the position desired.

The drill reached the bottom, despite many difficulties, and began drilling. The first sample, taken from below the layer of sediment, contained basaltic rock. This compact bluish substance, transformed by the pressure, was more precious to the men who brought it up than the most precious of metals.

Drilling had to be abandoned at a depth of only 196 metres. It seemed to be a case of either rock too tough for a diamond drilling bit or too costly a project to be continued. At any rate the Americans, having made the first step, abandoned the project. A fragment of the basalt they had obtained was presented to the U.S.S.R. Academy of Sciences, which is also preparing to join in the common effort to penetrate the mantle.

The Soviet project provides for the drilling of five boreholes from ten to fifteen kilometres deep, signalling the start of the journey to the centre of our planet.

Drilling will be undertaken in the vicinity of the Caspian Sea, in the Urals, Karelia, Transcaucasia, and the Far Eastern Region, all in the U.S.S.R.

This plan will assure the penetration of the sedimentary layer on the continental plain and in the foothills, in the area of older rock, and where the process of orogenesis is still going on.

The drill will reach both granite and basalt, for there is no sedimentary rock on the Karelian granitic shield, while on the basaltic base of the Caucasus region its layer is unimportant.

The fifth borehole will be drilled on the Kurile Islands, where the distance to the Mohorovičić discontinuity (the upper limit of the mantle) is only twelve kilometres. It will therefore go right through the Earth's crust.

Drilling to such great depths on land is a difficult task, but it is bound to yield incomparably more valuable results than drilling only beneath the ocean floor. If all goes well we shall get a general vertical cross-section of the crust clear down to the mysterious subcrustal substance. When we bring this substance to the surface, an end will be put to the numerous discussions and disputes now going on.

One is inclined to wonder how it will be possible to bridge the gap between the current record of eight kilometres and the fifteen- and even twenty-kilometre shafts which the geologists propose to sink. The difficulties increase with depth; so much so that there is good cause to speak of a "depth barrier".

Come to think of it, however, quite a few formidable barriers have now been hurdled. Airplanes, to say nothing of rockets, have broken through the sonic barrier and attained speeds of several thousand kilometres per hour.

Achievements in space are recorded in terms of hundreds of thousands and even tens of millions of kilometres of distance from the Earth. In the Earth's interior, on the other hand, achievements have yet to pass the ten-kilometre mark.

Temperatures also increase with depth. Fifteen or twenty kilometres down, which is as far as the drill is expected to go, the temperature should be over 200°C; so that besides having to break through very hard rock the drill will have to withstand great heat. That means that it will have to be extremely tough if the shaft is to reach at least the upper limit of the mantle. An entirely different type of instruments will perhaps be used to sink such shafts; instruments operating on a different principle, which won't have to disintegrate rock mechanically, like the steel or diamond drilling bit. Ultra-audible sound, beams of electromagnetic waves, electrohydraulic discharges, detonation waves, plasma jets and artificial ball lightning are perfectly capable of doing the job,

so that even the hardest of rocks will lose out to the miner's new weapons. Such new types as the ultra-audible-sound drill, the blasting drill, the quantum drill and the flame drill are bound to entirely supplant or at least begin crowding out the older mechanical methods of drilling.

This does not exhaust the list of future accruals to mining equipment. We are faced with the task of reducing the present enormous labour input, not only that of merely penetrating into the hitherto inaccessible interior.

It has been estimated that 1,500 million tons of rock must be worked every year in man's quest of ore, coal, shale, and petroleum. That is a truly labour consuming task, and it would be unreasonable to persist in this practice. This is where chemistry will be called upon to play the novel role of a miner, in association with high pressure, energy, and temperature physics.

Such powerful electric discharges or magnetic fields as are created artificially are not to be found in nature, or at least not on the Earth. Nature has probably nothing to offer that could compare with the effect chemistry is able to produce in the substance of the Earth's interior.

Once a shaft has been sunk, it will not be necessary to haul the ore to the surface, because either some suitable solvent or an electric current could be directed down the shaft. A lake of ore will form underground, and pure metal will settle on the electrodes lowered into the Earth's interior. The solution could be pumped to the surface, and a chemical plant could be set up right next to the ore hole, whose operation would not be encumbered with waste.

There will be no point in delivering coal to the surface. Experimental underground gasification mines are already in operation, combustible gas being delivered from underground to power plant furnaces or to the combustion chambers of gas turbines. In coal mining, gas, boreholes, and automatic equipment underground will supplant, respectively, coal, mines, and human labour.

The new trend in mining is geotechnology, which is concerned with the development of new techniques of mining without resorting to mines or shafts. The possibilities opened up by geotechnology properly belong to the realm of fantastic fiction.

Reducing the process of ore formation, for which nature

requires millions of years, to an observable period is nothing short of fantastic. In time, ore will be manufactured out of raw material mined underground, where the geotechnologist will be able to recreate such conditions as are conducive to the natural formation of ores.

It has been established that bacteria devour the sulphur contained in coal, refine petroleum, and are capable of selective storing of certain elements. It is suggested that the ferromanganese concretions strewn over the ocean floor are the work of bacteria. So that it takes no violent stretching of the imagination to visualise bacteria put to mining raw material.

As we go down deeper and deeper into the Earth's interior and take more and more out of the underground storehouse, we shall have to resort to new methods of operation. Sinking shafts will become impossible after the first few tens of kilometres will have been achieved. Not even in the very distant future will a shaft be able to penetrate really deep into the mantle.

Meanwhile, a journey into the Earth's interior would be tremendously interesting, especially for science, since it could provide answers to a multitude of questions regarding the structure of the Earth's innermost layers and the past, present and, to some extent, the future of our planet.

It would be of interest from the standpoint of practice, for it is the only way of reaching the treasures and the sources of energy hidden away in the depths of the mantle.

The Earth's interior is quite properly called the geocosmos; formal resemblance had nothing to do with the choice of the term. Both—the cosmos and the Earth's interior—are full of riddles. The substance in the one and in the other is in a peculiar state, that of plasma. Throughout the universe plasma exists in a rarefied and cooled condition, but in the terrestrial core, if it is to be found there, it must be heated and compressed. In either case it is a mixture of electrons and ions containing an accumulation of energy. This natural plasma of the inner core may possibly be developed in time.

The instability of the substance of the Earth's interior has other implications. The special conditions in which it exists, the temperatures and pressures, produce stresses in the rock. These stresses tend to accumulate and in turn produce upheavals and displacements, releasing vast quantities of

energy. A heavy earthquake is equivalent to the detonation of hundreds of hydrogen bombs.

Shall we ever be able to convert this geological energy into some other, more manageable (and, naturally, harmless) kind of energy? The deep strata of the Earth are sometimes likened to the dielectric of a capacitor: if we ever learn how to discharge the electricity in it the Earth will become one more source of energy.

A way may be found to control earthquake foci and volcanoes with a view to preventing seismic upheavals and eruptions. If we allow ourselves a flight of fancy we may imagine that by conquering the Earth's interior we shall be able to put to work the vagrant telluric currents which are similar to the currents of the ocean and the terrestrial atmosphere.

It is not ruled out, moreover, that the purely scientific discoveries which will undoubtedly be made during the journey towards the inner core will also be useful in a practical way. Once we discover the secret of the genesis of petroleum we may learn to produce it artificially, like the ores.

To make the journey we shall need what may be called "subterranean cruisers"; robots for the initial journey, and manned vehicles later. Here, too, there is a similarity between the geocosmos and the cosmos: automatic satellites were sent up first, and these were later followed by manned spacecraft. It might be interesting to note that these subterranean cruisers of the future are already familiarly referred to as geological satellites or subterranean rockets.

In regard to the tasks to be performed the geocosmos presents as many difficulties as the cosmos. As a matter of fact, the construction of a subterranean vehicle seems to be more difficult than that of an interplanetary rocket.

There will be no empty space to traverse: the vehicle will have to work its way through layer upon layer of hard, compressed rock, and the pressure will steadily increase, reaching three and a half million atmospheres in the centre of the planet. Temperatures, too, will mount to around four thousand degrees C.

Vehicles designed for more limited geocosmic travel will run into extremely difficult conditions, such as even bathyscaphs failed to encounter when submerging to the greatest depths.

Subterranean cruisers, or geocosmos vehicles, will travel towards the Earth's mysterious inner core

Here again we shall have to turn to superdurable and heat resistant alloys.

The subterranean vehicle will have to bore a shaft in the rock mass, which becomes more and more compact as the depth increases. The disposal of disintegrated rock shall have to be managed somehow or other and steps taken to prevent the tunnel's walls from crumbling and crushing the vehicle.

Communication with the surface shall have to be provided, and the vehicle's return must be guaranteed. The vehicle must have "eyes" and "hands", i.e., it shall have to be provided with instruments capable of working underground, where radio waves are unable to travel, standard optical instruments become useless, and where the crew members will hardly be able to leave their vehicle.

To work a passage through the rock it will probably be necessary to use a quantum drill with its disintegrating beam. Atomic batteries will supply energy for locomotion.

Chemistry shall probably have to be called in to strengthen the tunnel's walls in the vehicle's wake. The vehicle's sense organs will be operated by ultrasonic and electronic devices. In the event of disaster an artificial atomic blast will serve as a seismic signal which will be received from no matter what depth.

Continuing our analogy in regard to the cosmos, the ocean and the Earth's interior, or geocosmos, we speak of "navigation" in all three elements. But there is still another common feature: when a satellite is placed in orbit it enters the state of weightlessness: so does a subterranean vehicle upon reaching the centre of the Earth.

Weightlessness is no obstacle, of course; men have experienced it time and again; and it will be quite some time before we reach the centre of our planet. There is another obstacle, however, of a much more serious nature.

A manned satellite can interrupt its flight at any given moment and make a landing. Communication with such a satellite has undergone many a test: radio waves travel freely through the ionosphere, and the cosmonauts can be seen on TV as well as heard. Spacecraft launching and flight devices assure a degree of precision in placing the ships in orbit that will shortly enable them to meet, and to provide assistance in case of need.

Things are different in the geocosmos. Once deep in the Earth's interior, it is not so simple to turn about and go back, nor is it less difficult to dispatch a rescue vehicle. The communication problem has not been solved, which is not surprising, since no sound-conducting channel has been found in the Earth's interior, such as exists in the ocean, for example.

It is too early at present to foresee all the problems which will confront the designer of a subterranean cruiser, which will be an entirely novel type of vehicle, for it will have to travel through a virtually unknown environment.

At present it is proposed to limit construction to small subterranean automatic satellites which will be expected to relay information from depths of a few kilometres. A subterranean cruiser in the strict sense of the term exists at present merely in barest provisional outline.

We mustn't forget, however, that while so far we have penetrated only into near space, we have already begun designing interstellar spacecraft, and the feasibility of flight to the stars is undoubted: it is only a question of time.

The same holds true of the subterranean cruiser: it is needed, therefore it will be built. It is hard to say when that will happen, but it looks as if we shall travel into the Earth's interior much earlier than to the stars. Interstellar craft may come into being only in the twenty-first century or even in the twenty-second; but a subterranean vehicle may be achieved in a matter of decades.

* * *

The unexplored is not limited to outer space, the ocean depths, or the Earth's interior: stretches of impenetrable jungle, inaccessible mountain ranges and other unpopulated areas also await exploration. Such lands cover extensive areas, and if this virgin country is brought under cultivation enormous additional quantities of food, raw materials and energy will become available, which it is impossible even to estimate with any exactness at the present time.

The conquest of such virgin areas will require new devices, just as does the development of the ocean depths and the exploration of Antarctica. It is worth noting that the development of this new technical equipment has already begun.

The first explorers of the South Pole had only dog teams and their own legs to rely on.

In our time Antarctica is reached by steamships, and scientific stations flying the flags of many nations are supplied by air with the necessities of life and whatever they need to carry on their work. They are in constant radio communication with the outside world.

Snow tractors, caterpillar-sledge trains, airplanes and helicopters are now at the disposal of those who live in the newly established scientific stations in Antarctica.

The snow-tractor, a sort of tank built for non-military purposes, is in reality a self-propelled dwelling fitted out to provide maximum comfort for its crew.

The outer door opens into a small vestibule, which in turn leads into a working room furnished with tables, large and small, armchairs, and bunks. The motor compartment, drying room and lavatory are next to it.

The galley equipment includes an electric range and airtight containers for use in cooking in a rarefied atmosphere. Meals are taken in the adjacent working room.

Forward of these premises is the wireless cabin, the chart room on the starboard side, and the driver's cabin with sleeping hammocks slung behind the driver's seat.

An air heating system provides sufficiently frequent complete ventilation in the premises. There is running water and a shower. The bunks are equipped with foam-rubber mattresses. There is also a laboratory, where crew members can work without going outside, for the recorders of the various measuring instruments have been installed inside.

Going outside of the machine is no extraordinary venture, incidentally, for the crew are provided with clothes specially designed for Arctic conditions.

To go back to the types of vehicles that shall have to be developed. Cross-country vehicles currently being built include several types: some are equipped with several pair of huge balloon-tyred wheels, some with spherical wheels, some with caterpillar treads, others with stilts, caterpillar-wheel combinations, etc., etc.; these can travel over roadless terrain. Attention is increasingly turning to cross-country air-cushion vehicles capable of travelling over land or water.

Wheel-type cross-country machines are also being developed.

To reduce surface load as much as possible, four-axle rather than two-axle machines are being designed, capable of climbing and going over difficult terrain. Oversize and dual tyres are used to this end.

Tubeless pneumatic rollers are also used for this purpose: these are rubber balloons filled with air under moderate pressure, which give as they roll over bumps on rough ground and keep the vehicle from floundering in snow or morass thanks to their low specific pressure.

Barrel-shaped (spheroid) tyres on multiple axles are another alternative. Travelling over roads, the "spheroido-mobile" rolls on its front and rear axles. On coming to marshy ground it lowers its intermediate axles, and special rubber belts form a sort of caterpillar tread over its unique wheels, increasing the bearing surface to many times its ordinary size.

Still another type of cross-country vehicle bears a vague resemblance to a rhinoceros, its driver's cabin protruding well forward. Hemispherical wheels along its flanks are provided with steel ribbing for better road adhesion and rubber plating to save the road surface. On marshy ground the hemispheres sink deeper, increasing the bearing surface.

The "rhinoceros" is amphibian: its hollow wheels, watertight body and hydrojet engine make it navigable even in shallow water and cluttered rivers.

Another type in this series of remarkable vehicles is a cross-country lorry on cushion tyres which it uses to step along bumpy roads and over water-logged terrain as well as to break through brushwood and undergrowth and scramble over forest windfalls, owing to the fact that its surface load is only from one-twentieth to one-thirtieth that of an ordinary lorry.

A variety of unique aircraft types is appearing, such as miniature helicopters, jet flying platforms, jet belts, etc. These belong to what might be termed minor aviation, which, however, has a great future.

Human ingenuity has been directed since long ago to the task of creating a universal vehicle whose forerunner may be found in the fantastic novels of Jules Verne, dating back to the 1890s.

The flying automobile is no longer a pipe-dream. Neither are amphibian and submersible automobiles. Experimental

models are in existence. Other ideas have been offered in this field, for instance, that of a flying submersible.

The time is not distant when a machine will be constructed, capable of travelling on roads and over roadless terrain, afloat and underwater, and of flying, using vertical take-off and landing techniques.

A machine of this type is theoretically feasible; it will become a necessity when the conquest of the virgin tropics is begun.

It is not a matter of mechanically combining different types of machines, of course; nor is an absolutely universal vehicle needed for every occasion.

In the tropics, it will be necessary to travel up and down rivers, where navigation is often fraught with danger. No ordinary craft would be able to negotiate cluttered up and shallow channels, take refuge in heavy weather, work its way through fallen timber or hug liana-overhung shores. An air-cushion vessel, especially one capable of submerging, is just the type that would be capable of ascending any stream into the hinterland.

For crashing through otherwise impenetrable tropical jungle a powerful tank-like cross-country vehicle will be used, possibly one equipped with either a caterpillar-wheel combination or a stilt-like walking device. There will nevertheless be areas heavily waterlogged during the rainy periods, stretches of impassable jungle, and extremely rough terrain, which will prove a barrier even for such machines.

The helicopter rotor will therefore be used where neither wheels, nor caterpillars, nor walking devices, nor air-cushions will do the job.

Explorers of tropical forests will have at their disposal specially constructed midget helicopters for investigating the upper tiers of the woods and miniature jet belts for hopping over obstacles tens of metres tall.

Automation will doubtlessly find wide application. The proposed cross-country submarine vehicle, for instance, will be a cybernetic machine capable of travelling over the ocean floor. There is no apparent reason, then, why a self-propelled automatically navigating exploration vehicle could not be used on land as well.

On such a vehicle, transmitters would be used for continuous collection of information on everything observed *en*

route. The data would be processed and evaluated by an electronic computer, which would make decisions and relay the necessary commands to the executive devices, such as to change speed or course, obtain this or that sample or probe, or photograph such-and-such an object with a film camera.

Miles away, the observer, seated in front of his TV screen at his station somewhere on the bank of a river or on the fringe of a forest, will see everything that comes to pass in the depths of the forest. He will be able to radio the robot vehicle new instructions in amendment of the previously established programme. Thus man and machine, working together, will be able to explore vast stretches of the forest.

The exploration will help discover and place on record the riches of the practically unknown tropical jungles of Africa and South America, and amend or revise the relative maps.

Unexplored desert areas will also be made to reveal their subterranean storehouses. It is high time to go after these lifeless, sunparched lands, covering tens of millions of square kilometres. Science and technology must join forces to do the job. A tremendous quantity of water will be required.

When this is done, life will be brought to the barren lands of Central Asia, the Middle East, Africa and Australia, where efficient modern agriculture will be introduced and developed. Water management will regulate the hydrologic cycle and steps will be taken to prevent the sands from ever again encroaching on the fertile lands.

Vast areas will be turned into grazing meadows for camels and sheep. The areas under crops will also increase.

It might be said at this point that we are letting ourselves be carried away by our imagination. For where are we going to get enough water?

The necessary water will be furnished by subterranean springs and neighbouring oceans (with the aid of desalting installations, of course). Moreover, moisture can be obtained from the atmosphere in those areas by means of special condensation equipment. The pattern of oases will expand, and reclaimed lands will gradually engulf the useless sandy wastes.

The "universal vehicle" will be capable of flight, vertical take-off and landing, road and cross-country, and surface or submarine navigation

The dearth of water will cease to exist as soon as all the power resources are brought into play and energy becomes available in sufficient quantities. Deserts and semi-deserts will yield ground to crops and meadows, orchards and woods; and only bits of desert here and there will be allowed to remain as exotic attractions catering to the tourist trade.

We have seen that the water supply is a problem in the desert and semi-desert areas. There are areas, however, where, on the contrary, there is an abundance and even a superabundance of water, and here the problem is that of building a network of drainage canals. A method of dealing with swamps, which also cover a substantial area of our planet, will be found, just as in the case of the deserts and semi-deserts.

A very important reservation must be made at this point. The current level of technical development and the coming abundance of energy offer ample opportunity for the exercise of imagination in the field of engineering. There is already a plethora of astounding projects designed to rearrange things on the Earth and even elsewhere.

We are not referring to widely familiar projects like building a dam across the Bering Strait, or creating a ring around the Earth to reflect the sunlight and thereby making our planet look like Saturn, or creating a second, thermonuclear sun for ourselves, or changing the direction of the Gulf Stream, or using atomic heat to warm the ocean.

Bolder schemes have been advanced, such as that of deflecting the Earth from its usual orbit; inducing faster lunar revolution by using thermonuclear charges or forcing a collision of the Moon with an asteroid; and creating an artificial atmosphere around the planets.

Leaving the purely cosmic schemes out of the discussion, it is important to sound a warning in regard to so immediate an object as the Earth we live on. Granting that much of this is not so fantastic from the standpoint of technology or engineering and does lie within the realm of feasibility in the near future, if not today, it is important to reckon with the main factor, i.e., Nature.

How will it react to man's intrusion, his efforts to change its processes, to modify the established balance?

What if by melting the ice in a given area we will initiate glaciation in another? Or having reclaimed barren deserts we

will endanger lands already under cultivation, so that deserts will disappear only to reappear elsewhere? Might not a somewhat rash interference in the global climatic regime cause more harm than good?

Nature is extremely sensitive to any kind of influence brought to bear upon it. Any activities of global portent must therefore be considered with circumspection and prudence. Every such project must be subject to the joint decision of engineers, economists, geographers, and biologists.

* * *

One wonders what might come to pass in outer space while we are busy studying and developing the Earth on which there is still so much to learn and to be done. Perhaps events there will precede those in the World Ocean and a journey to the Moon will become a fact before a journey to the centre of the Earth. Whichever way things turn out, an effort has been launched to achieve a wide variety of objectives. Right now, to be sure, one can discuss with certainty only one particular impending development.

Among the many man-made stars that may spangle the sky, one that will appear in the relatively near future will eclipse all the others. To us on the Earth it will probably appear much brighter than Venus as it sails daily across the heavens. It will be a regular dwelling, whose design is already being planned. Its model exists in the shape of the early manned spaceships, which may actually be considered space stations of modest size.

Men lived and worked in these space stations, even if for brief periods of a few days, observing and filming our planet and recording their observations by means of instruments and entries in their logbooks. They were in continuous wireless and TV communication with the Earth. Plants and animals accompanied the crews of these satellites.

If there had been certainty of a safe return, a man could have been sent aloft even in the third Soviet satellite. This third satellite weighed nearly one and a half tons, or only a little less than the manned American spaceships *Sigma, Friendship*, and *Fate*.

The Soviet designers, however, preferred to adhere to their original programme of developing heavier and heavier satel-

lites for near-Earth flights, until their weight was increased to more than thrice the weight of the third one, and until a high level of comfort was reached, as in the spaceships *Vostok* and *Voskhod.*

They were, in fact, more comfortable than a modern airplane. The cosmonauts breathed freely, carried out all the provisions of their programmes, and took time out to relax. They could unstrap themselves from their seats and float around in their cabin. More than that: wearing a space suit a Soviet cosmonaut stepped outside his ship and actually floated in space. A similar feat was later accomplished by an American astronaut.

Space rations, wholly "cosmic" during the early flights, comprising juices and pastes in tubes, became more and more "earthly". While the cosmonauts missed the familiar landscapes, they were regaled with cosmic vistas. Radio waves assured constant news from the Earth and, in turn, relayed information and TV pictures from the spaceship.

The Soviet and American cosmonauts' successful flights are tangible forerunners of the future developments which are the subject of the present considerations.

Manoeuvrable satellites already exist, which change from orbit to orbit upon a command from the Earth. Meetings in space and the feasibility of junction, construction operations in space, in other words, may now also be discussed with certainty.

All of this goes to explain why we have come to treat the numerous semi-fantastic descriptions of permanent orbiting stations as something approaching achievement. Still, we should not overlook the fact that many great difficulties must yet be overcome.

Let us imagine that rocket parts and prefabricated elements specially placed in orbit have been assembled into a space station–surely one of the most unique structures ever attempted by man.

The designers will see to it that a compromise is achieved and requirements are met which are often mutually contradictory. Durability, for instance, must be combined with lightness, because delivery of every kilogramme of material to a spacial destination calls for the expenditure of a great amount of energy. Material will therefore be needed which will ensure sufficiently durable structures at no extra weight.

The rule applies to all the types of equipment and installations required to assure livable conditions on board a spaceship, and therefore a space station, for the latter is also a variety of spaceship orbiting the Earth.

How many revolutions is a space station destined to make? How many years will it survive? Designers estimate its lifetime in terms of years, but it is possible that, once in orbit, it will remain the Earth's satellite for ever, like the Moon.

Its crews will be replaced at regular intervals. The range of its programme will widen: initially an explorer of the Earth, the Moon and the planets, and a trans-atmospheric observatory, it will later be turned into an intermediate base for launching ships into outer space.

The customary conditions obtaining on the Earth will have to be recreated, in miniature, on the space station. Designers of space settlements will have to solve such problems as breathing, nutrition, protection from meteors and radiation, artificial gravitation (even though this will be less than on the Earth). There will be other problems, too, belonging in the field of medicine, however, rather than engineering.

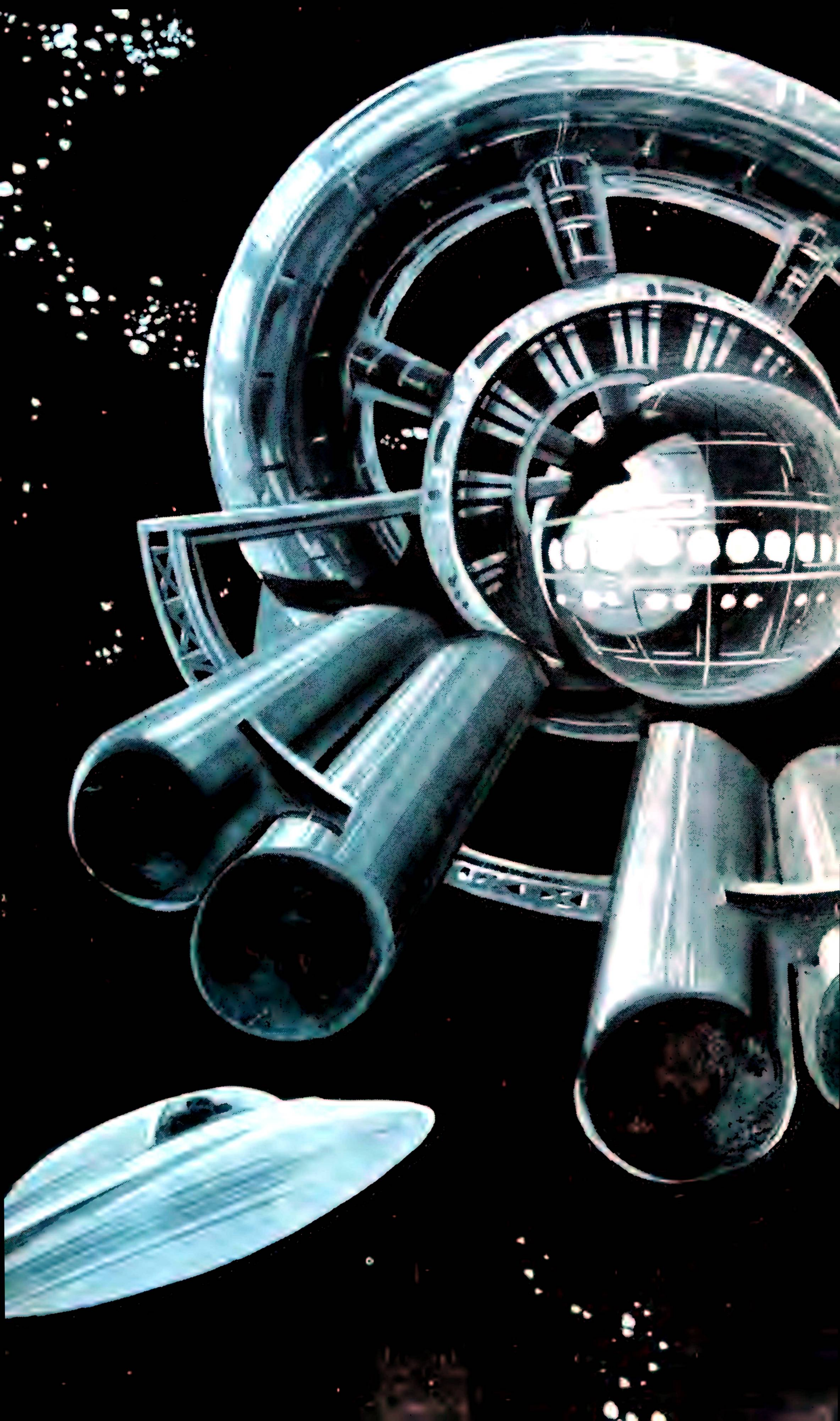
Living conditions and surroundings must be such in every respect that will relieve any possible nostalgia. Specialists in space psychology are even now drawing up the required recommendations, and physicians are acting as advisors to the engineers. As a result of this co-operation between the engineering and medical personnel the general outlines and separate elements of the Earth's future spacial affiliations are beginning to take shape.

There are thousands of provisional blueprints of future space stations in existence in many lands. Conceptions differ greatly: from a long-term satellite spaceship manned by a crew of one or two to a whole settlement in interplanetary space, with a population running into thousands.

Specialised stations are proposed for either geophysical or astronomical observation, and also stations of a universal or multipurpose type, equipped for work in all fields.

Populated satellites are envisaged on orbits at limited distances from the Earth and tens of thousands of kilometres

The space station of the future will serve a laboratory for studying the Earth, the Moc and the planets. It will also be a sprin board for inter-stellar flights



away. Migrant stations have been suggested, which would shift from orbit to orbit under their own power.

There are schemes, finally, worked out with an eye to a very distant future indeed, which envisage stations near the Moon, on the planets, large and small, on the planets' satellites; stations which would become minor man-made planets travelling around the Sun after the manner of the regular members of the solar system.

It is worth noting that many engineers suggest using satellites as springboards for Lunar, Martian, and other similar flights. That extraterrestrial stations might be used to assemble interplanetary spaceships is within the realm of possibility. Interstellar spaceships, too, will be assembled outside the atmosphere, though not for a long time to come, of course.

Is it possible that interstellar space will itself be helpful in interstellar flights? We shall try to answer this question, though without going into the details of interstellar spacecraft construction.

An interstellar spaceship is bound to encounter gas-dust clouds, since the density of the gas that fills the universe varies from place to place. It will have to fly through streams of interplanetary plasma and highly ionised gases, as well as hydrogen, sodium, calcium, and titanium atoms.

The possibility is not ruled out that interstellar spacecraft will be equipped with a jet engine using interstellar gas after the manner of the air-breathing jet engine used in aircraft. It is hard to say at present what such an engine would be like.

Perhaps it will "suck in" gas particles to increase mass outflow and consequently jet thrust. Perhaps it will transform this interstellar substance into radiation to help the propulsion jet overcome the by no means empty void through which the ship will travel towards the stars. The thrust, however, would still be insufficient.

Whatever the case, free energy in outer space is not to be discounted when refuelling for interstellar flights.

No matter how fantastic these "interplanetary" and "interstellar" schemes may sound at present, the outer space will eventually be conquered.

This conquest will vastly enrich our knowledge of the universe around us. The few years that have elapsed since

the initiation of the cosmic age have given us more than the many decades that preceded the satellites and rockets; and our advance is gathering speed at an incredible rate.

The Moon and the neighbouring planets have drawn closer. The time is coming when rockets will set off towards objectives in the far reaches of outer space.

MAN'S CONTEST WITH NATURE

As soon as man took cognition of himself he entered into what may be called a contest with Nature, that is, the physical environment that he perceived unfolding before him in all its endless diversity. Phenomena which have completely lost their mystery for us were, in the early stages of man's development, pregnant with deep and more often than not mysterious meaning. Things which we look upon as trivial today were to him a revelation.

Nature was for a long time peopled with gods, and even the simplest phenomena were thought to have a subtle, preternatural cause. This probably explains why the process of man's cognition of his physical environment lasted so much longer than might have been expected.

Eventually, however, the exigencies of mere existence forced the tendency to wonder "why?" and "how?" into the background. It may be interesting to wonder why the wind blows and why the river flows, but it is much more useful to actually operate a windmill or a waterwheel. At the outset the assertion of man's command over his physical environment proceeded in a chaotic manner, and practical experience was his sole criterion and guide. We owe our earliest inventions essentially to pure chance, and the inventor's progress was a good deal like stumbling about in the dark.

Man's discovery of iron, for instance, is explained in different ways. Some hold that our primitive ancestors found a piece of an iron meteorite which had fallen out of space. Others think a campfire may have been built over some chunks of scattered ore. Whatever the case may have been, iron hatchets and iron arrowheads came into use: the stone age was over and the iron age had begun.

The idea of a raft may have been suggested by the sight of a chip of wood floating down the river or a tree trunk

washed ashore. Whatever it was, it led to raft, boat and ship, and the assertion of man's mastery over the ocean in the end.

We couldn't grope our way all the time, of course and only the early discoveries, although they were of paramount importance, were due to chance.

It is interesting to note that ages ago, when the veil that concealed his environment first began to lift, man started to look for the cause of things.

The indivisible atom is a concept developed many centuries ago. Even before the structure of the atom was known and the existence of an infinite universe within it suspected, man put to work such phenomena as the transformation of substances, transition of electrons, the complex molecular and atomic mechanisms, the gamut of colours; in short, the entire range of phenomena characteristic of the activated atom.

Many natural phenomena were only observed with no thought of the possibility of their being put to use, to be sure.

No one, of course, could have been expected to divine the model of a controlled electric discharge in a flash of lightning, or that of a daylight lamp in a glow-worm. No one could have suspected that the squid embodies the principle of a hydrojet engine and that the bat is a natural sound locator.

Observing, wondering, and reflecting, man gradually discovered more and more of the principles underlying his physical environment. Penetrating into the innermost nature of things he found that the simple occasionally turned out to be complex; and the complex sometimes proved simple, but only to confront him with new problems at a later stage.

Finding answers to the mysteries around him, be it steam in the boiler or the electricity which was discovered in amber and became, along with steam, the symbol of a new era, man steadily increased his knowledge.

One such achievement was to solve the riddle of the atom. The microcosm, of which we had formed so definite a conception, presented a new aspect to our gaze. Going back to the atom, and splitting what we believed to be non-fissionable, we came to observe how the microcosm manifests itself in the infinite.

Imperceptible but very real particles and real but not necessarily perceptible fields are active in this infinite universe. The endless diversity of natural processes and phenomena is the product of this intricate play of interacting forces.

The 20th century has seen an unprecedented acceleration of such discoveries. It has taken only a few decades or even years to reach the present level of knowledge in regard to particles and fields, the gossamer structure of matter, and the nature of faraway galaxies. Yet the tempo continues to accelerate.

Like all the arsenal of science, the instruments responsible for an enormous extension of our sense organs are steadily being perfected. A proton synchrotron of 10,000 million electron volts was constructed only a few years ago, yet immensely more powerful nuclear artillery is already being designed. The possible effect of instruments which will cross the present threshold of sensitivity and the possible results of our growing control over substance are even now topics of discussion.

Accelerators are coming, as powerful as those of Nature, where electromagnetic "slingshots" scattered in the universe disperse particles and send them hurtling millions of light-years away; and perhaps even more powerful.

So are particle "factories" creating anti-matter as in Nature, where accumulated anti-matter possibly builds up to form entire anti-worlds.

Electric and magnetic fields are coming, characterised by tensions and intensities like those in Nature and, perhaps, even greater.

And, finally, substance compressed to stupendous density as in the stars known as white dwarfs, rarefied and heated as in solar plasma, or cooled to practically absolute zero as it is possibly cooled in interplanetary space.

In their contest with Nature the physicists have scored quite a number of successes. Yet the victories won do not diminish the number of battles that lie ahead. The challenge of this pursuit of the elusive lies in knowing that the pursuit will never end, that we and the future generations are destined to wage these battles for ever, knowing the joy of victory and the bitterness of defeat, and that the mysteries solved and great discoveries made are to be our reward.

This contest between man and Nature transcends the spheres of the microcosmic and the universal, or the two extremes, so to speak. Man-made infra- and ultrasonic oscillators are not worse but better than Nature's. Man-made instruments give a light more brilliant than sunlight. And the natural bolt of lightning is a poor competitor of the

discharge produced in the physicist's laboratory. The radioactive elements which constitute Nature's source of atomic energy have been outstripped by man's nuclear reactors. It is within our power to put a substance through all of its states, which are now known to be four in number, including that of plasma.

Theoreticians among the physicists list as many as seven states of substance by adding the neutron state produced by immense pressures "squeezing" electrons into the nuclei and producing uncharged neutrons; the epiplasmic, which is a mixture of particles and antiparticles in equal numbers, produced by rapid compression and extreme heating; and the "physical vacuum" or radiating field. These seven states of matter are inseparably interrelated.

A good many mighty natural phenomena can be produced artificially. Shock waves have been produced in laboratories, for instance, resembling those produced by the falling of a gigantic meteorite. Gases in discharge tubes luminesce in the same manner as the air at great height under the impact of electrons arriving from the Sun. Wind tunnels and hydrodynamic tunnels recreate the flow of air or water. Chips cast off a rocket in flight reproduce what happens when actual meteoric bodies enter the atmosphere.

Long before the airplane or the spaceship take off their models undergo, in miniature, all the tests which the one or the other will have to pass in practice.

While we are on the subject of models, we might say a few words about a model which is non-existent at present but which is bound to be constructed.

It is proposed to construct a laboratory model of the Earth. It is to be sizable affair, though infinitesimal by comparison with the subject. Appropriate materials will be used to construct the crust and the interior layers. The model will reproduce the movement of the subcrustal substance, the eruption of magma, the accumulation and release of energy in the interior of our planet; in brief, it will reproduce all the aspects of our planet's life.

With a bit of imagination we can visualise working models of Mars, Venus and Jupiter, and, sometime in the future, type models of other planets, belonging to stellar systems other than the solar.

This must not be taken to mean that we have learned to

reproduce all the physical processes that go on in Nature, though what we have actually done has yielded astonishingly big returns in the shape of motors, from steam engine to atomic propulsion, electronic instruments, hydrofoil ships, speedy airplanes, space rockets, etc.

Chemists, too, have joined this contest with Nature and may be justly proud of their achievements, some of which have even surpassed what Nature is able to do. Thus, they have learned to rearrange at will the pattern of molecular structures, working from blueprints like architects, and creating substances having predetermined properties.

Modern chemistry might well be called a replica of Nature, for it makes artificial wool, silk, leather, furs, paints, and rubber. In fact, it makes a number of things that Nature is unable to create, such as materials which are unsinkable, impervious to acids or alkalis, and fully as durable as metal and as hard as stone.

Water-repellent and non-creasing fabrics cannot be manufactured from natural fibre, just as foam rubber cannot be produced without chemicals. As a result, the activities of chemistry have become as widely diversified as the works of Nature.

While certain activities are carried on by the chemists independently, there is close co-operation with physicists and geologists in other fields, for instance in the recreation of the processes going on in the Earth's interior.

Natural laboratories exist in space and in the Earth, including the crust and the deep interior. A great variety of transformations take place tens and hundreds of kilometres beneath the surface, where Nature's own geochemical plant turns out minerals and ores for our use. Substances undergo astonishing transmutations in the high temperatures and tremendous pressures of the lower layers.

The hardest of diamonds are produced here, and families of precious and semi-precious stones. One wonders whether we might not learn from Nature to make these stones. The answer is that we can, and the artificial diamond is conclusive proof.

Perhaps the greatest difficulty in solving the problem lay in the fact that no one knew the necessary preconditions, i.e., the values used by Nature in creating a diamond, for instance. It may be a matter of x degrees and y atmospheres

for all we know. The various values admit of numerous combinations, but it is essential to find the one and only among the many that are possible.

The quest continued for nearly a century, the early efforts being concentrated on applying pressure alone to turn soft graphite into hard diamond, and high temperatures were resorted to only when these efforts had failed.

Sensational reports stirred the world from time to time: a laboratory furnace had allegedly yielded the coveted crystals. The reports turned out to be false, though they were rarely deliberate falsehoods. Something or other always went amiss in these experiments, which was hardly surprising, for the experimenters were groping in the dark.

Success came only when the method of converting the graphite lattice into a diamond crystal lattice was theoretically figured out. The 200,000 atmospheres and 4,000°C did the trick, as predicted by the theoreticians.

The diamond episode is now a thing of the past. Artificial diamonds are now manufactured like artificial rubies or sapphires. They cannot compare with the famous stones; they lack the breathtaking sparkle and do not fetch the fabulous prices of the big unique diamonds that have been given proper names.

A much greater price has been paid for them, as a matter of fact, when one considers the magnitude of man's accomplishment: for, having penetrated the mystery of the process in the Earth's interior, he has succeeded in recreating that process.

One might have thought that the hardest substance on Earth had been created: but the quest was actually carried on, and science produced a still harder substance, which has not, so far as we know, been discovered in Nature.

A diamond scratches glass; but is there anything that will leave a scratch on a diamond? Until quite recently the answer would have been negative. At present, however, the answer is borazon, one of the newest achievements of science.

Right now geologists are serious about the possibility of producing artificial ores. Nature would be called in, or useful microbes, to be more specific, and a variety of powerful physical and chemical aids, in order to accelerate the process of ore formation and to accomplish in a matter of years

what it has hitherto taken geological periods to accomplish. There is plenty of raw material in the Earth's interior, as well as high pressures and temperatures, so that it is only necessary to introduce an accelerating catalyst to bring ore deposits into existence at will.

The contest with Nature that we have been discussing is carried on in many different fields. Lately it has extended into the field of engineering.

There is no denying that engineering has risen to unprecedented heights in our time. Every new machine has been looked upon as a technical wonder in its day: the ungainly early models of the automobile, for instance, or the flimsy contraption which actually did leave the ground and was given the high-sounding name of aeroplane now make us smile. Speedy luxury motors have become commonplace, and we are getting used to supersonic planes.

Yet even the luxury motors and supersonic planes of today will seem to our descendants fit only for museums. We, ourselves, have ceased to consider miraculous a computer capable of performing hundreds of thousands of operations per second or an automatic interplanetary station which communicates with the Earth at a distance of millions of miles, despite the fact that modern machines are really marvellous achievements.

However, were we to ask our inventors if they thought that they had done all they could to catch up with Nature and do even better, the answer would be a regretful "no".

For it still remains to learn to fly after the manner of birds, i.e., to build a machine with flapping wings as perfect as those of a bird;

to construct a subterranean cruiser capable of burrowing like a mole;

to design a submarine as swift as the porpoise;

to construct instruments capable of seeing, hearing, touching and smelling with the sensitivity of an animal;

to invent jumping devices which would aid us jump as high—relatively to our size—as do some species of insects and animals;

to design sound-locating instruments as perfect as the natural locators of bats and porpoises;

to construct instruments as highly sensitive to changes in an electric field as a fish, which senses currents of a thou-

sandth of a milliampere, and to changes of an amplitude of less than half the diameter of a hydrogen atom, as a grasshopper.

The animal world has its own wizards in many lines, and try as we might, we have so far succeeded in excelling them only in a few respects.

The ornithopter, an airplane provided with flapping wings, is still being designed. The subterranean cruiser, or mechanical mole, exists only as a model. New submarine hulls with a finish resembling the skin of a porpoise are currently undergoing merely preliminary experiments.

The eye remains the most perfect of optical instruments, even though modern electronics do substantially increase our natural range of vision. Wearing a jet belt, man could outstrip the best jumpers in the animal kingdom. Water jet engines, repeating in principle the natural jet propulsion equipment of the squid, are already in use.

Inventors have still a great deal to learn from Nature. We shall doubtlessly learn much by observing the flight of birds and insects and studying the ingenious mechanism of adaptation developed over the age-long process of evolution of living beings from a simple to a more and more complex state. Superspeed film cameras, roentgenography, high-precision instruments and a diversity of refined examination techniques will be used to this end.

What has been said above does not constitute a programme for inventors or scientists; but the inventions and discoveries mentioned are practically on the verge of realisation.

Among these are artificial green leaves, capable of utilising sunlight just like natural leaves; artificial luminescent substances and colours similar to those that are characteristic of benthic fishes; and artificial arms controlled by bioelectric currents, like the human arm.

Man must be able to dive to depths of a kilometre in the ocean, like a whale; and to grow new limbs in case of loss, like hydras and lizards; also to develop a state of suspended animation, or anabiosis, like a hummingbird.

This brings us to another technico-biological problem. Working together, biology and technology, once again in competition with Nature, are trying to create an artificial environment for us, also referred to as microenvironment, microclimate or bioclimate.

Water, the rarefied air of great heights, and the cosmic void are all environments where human life cannot be sustained. It is not enough to protect man from the pressure of the water column or from the vacuum, whether partial or complete. A self-sufficient microenvironment, having all the attributes of man's natural environment, must be created within the gondola of the bathyscaph, the cabin of the stratosphere balloon, the submarine hull, or the body of a spaceship.

The artificial microenvironment is one of the greatest achievements in the field of technology and science. The subject was first broached by Dmitry Mendeleyev, who suggested the idea of a hermetically sealed cabin for the stratosphere balloon. Yet his idea was first applied to submarines, rather than to stratosphere balloons. It was later applied to the airplane fuselage, and several ascents have been made in stratosphere balloons equipped with hermetically sealed cabins.

The necessity grew more imperative as time went by. Up to a certain time stratosphere balloons made only occasional flights; submarines long remained submarines in name only, for actually they effected relatively brief submersions rather than real underwater voyages; airplanes had just begun their conquest of the stratosphere; and rockets did not attain substantial heights or carry passengers.

Then the situation changed radically: fliers, submarine crews, stratosphere balloon teams, and spaceship pilots—a new profession—developed an urgent need for the artificial microenvironment.

Submarines now justify their name, for atomic submarines, unlike the ordinary type, cruise most of their time in the ocean depths. The stratosphere balloon is still in use; besides setting an altitude record of somewhat over 30 kilometres for balloons, it has facilitated certain extremely interesting observations.

Thus, flights into the stratosphere made in recent years have furnished answers to a number of questions. Do plant spores reach the stratosphere? How do instruments perform there? How does a man feel after 24 hours at record altitudes for stratosphere flights? In the absence of satellite observatories, can a stratosphere balloon take a telescope up to the limits of the dense layers of the atmosphere in order to escape the ever-present obstruction of air?

The ceiling for planes has also reached the stratosphere in the post-war years. Passenger planes now fly at altitudes of eight and even ten thousand metres. To put it differently, thousands now spend hours in conditions where life would be impossible without the special microenvironment.

Military planes climb even higher, overtaking the stratosphere balloons, which means that they have passed the 30-thousand kilometre mark. As to experimental rocket airplanes developed in some countries, which are able to fly in a nearly complete vacuum—these may soon cross the one-hundred-kilometre line and thus find themselves in the ionosphere.

Whether winged like an airplane or wingless, rockets make brief flights, but nevertheless have to be equipped with hermetically sealed cabins, or else space suits must be worn by their passengers.

For about a decade, Soviet rockets carried dogs and other small animals on board. Dogs were the first to test the biosphere of a spaceship in a 24-hour flight. Laika, Belka and Strelka, Chernushka and Zvyozdochka, performed as space test fliers and showed that highly organised beings can survive flight in space.

Manned satellite spacecraft came next, setting new space records of ninety-minute to eight-day flights and from one to as many as 120 revolutions around the Earth. In the future, no doubt, man will remain in the cabins of spaceships for much longer stretches of time.

Outside air can be breathed within the cabin of an ordinary airplane, as it is introduced by means of a compressor. Submarines surface from time to time. The closed environment designed for deep-water oceanic research and space probes, on the other hand, must be entirely self-sufficient. It must assure protection against a multitude of dangers and enable the passengers of the vehicle to live and work in extraordinary conditions for longer periods at a time.

This microenvironment comprises a number of systems, the very word indicating the complexity of what has had to be designed and built.

The cosmonaut's workplace is slightly roomier at present than that of a fighter pilot. A great variety of instruments, mechanisms and installations have had to be crammed into

this limited space, such as air-conditioning equipment to purify the air and maintain desired humidity, temperature, and pressure. An artificial bioclimate has thus been achieved, subject to automatic or manual control.

Subsequent manned spaceships were provided with more spacious and comfortable cabins, equipped with seats that are quite a system in themselves inasmuch as they enable the pilot to work in comfort, i.e., to carry on his observations, keep his records, operate his film camera, keep in touch with the Earth by wireless, and relax.

The walls and observation ports of these spaceships afforded reliable protection against extremes of cold and heat, the thermal insulation of the ship's skin being able to withstand temperatures of up to 1,000°C, which develop when the ship re-enters the Earth's atmosphere. The ship's personnel is protected against the perils of radiation, and the ship itself is impervious to micrometeoric bombardment.

It would be wrong to conclude that the problems of the microenvironment have all been solved, for new ones will inevitably arise as the probe of outer space continues. They will be encountered in such fields as air-conditioning, feeding the personnel, providing protection against all eventualities, planning the daily regime.

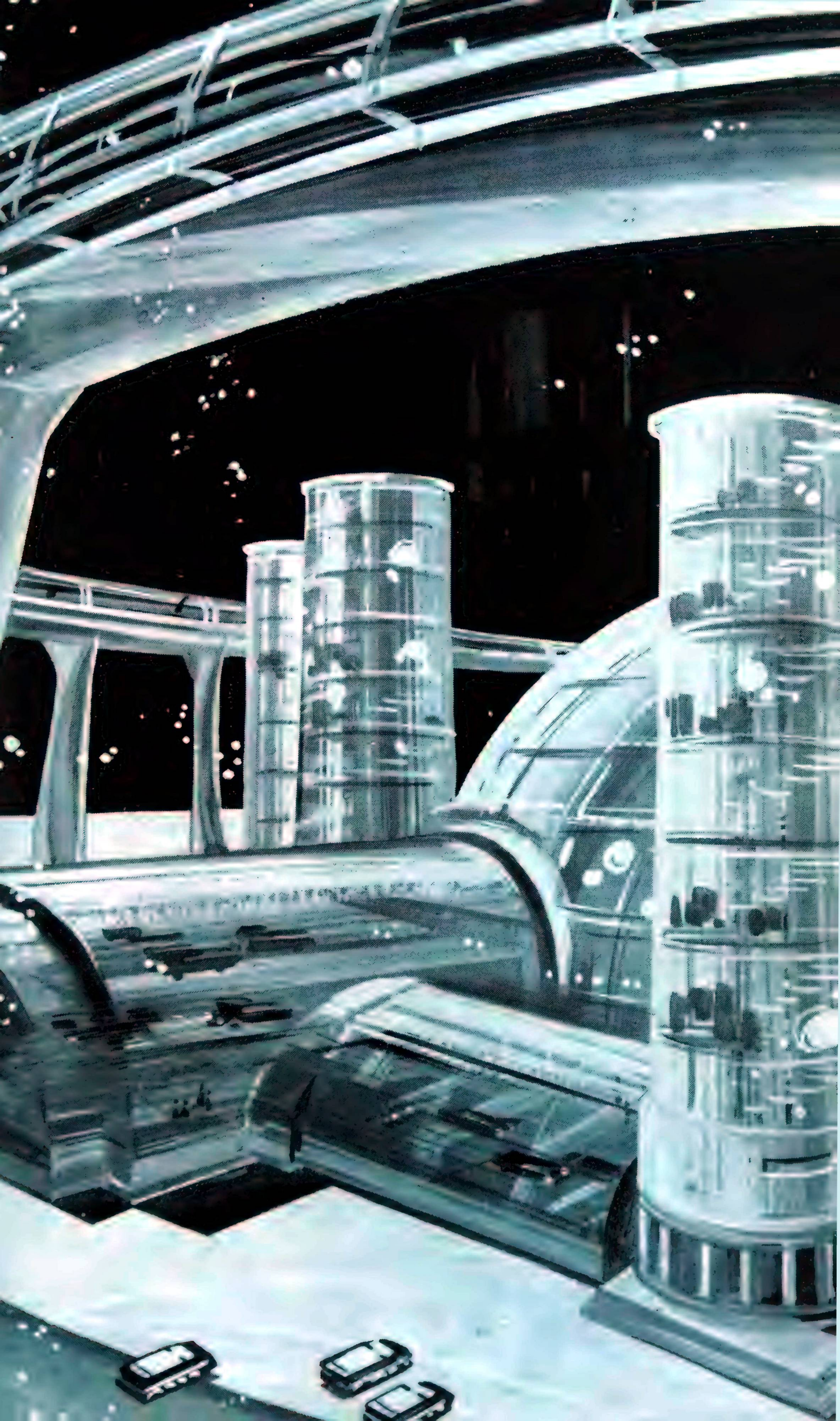
If one were to ask why new problems should arise and why the requirements of distant flights should differ from those of flights in the Earth's vicinity, it would be necessary to refer to the conventional preliminary calculations and to certain established facts.

Even so modest a project as a flight to the Moon implies several weeks away from the Earth, while journeys even to the nearest planets will take many months, possibly years. Space station personnel, inhabitants of lunar settlements, and observers stationed on some planet's satellite will remain on duty for considerable periods at a time.

Interstellar journeys are a matter of the distant future, of course; but we know that they imply decades rather than years of travel.

Storing aboard oxygen, water and food enough for journeys of that length is out of the question for the simple

Roofed cities will be built in the frozen North. They will have their own electric sun, microclimate, subtropical plant-life, and even swimming pools and beaches



reason that no ship would be able to carry the fantastic quantities required. It is impossible to rely on food concentrates or synthetic foods alone, on the other hand, nor are any supernutritive and extra-lightweight foods of that kind available at the present time.

Moreover, a chemical plant for recreating an artificial atmosphere in a spaceship will function for only a limited time; and drinking water cannot be supplied to last even an average journey, let alone flights to distant planets.

It appears that we must turn to Nature in our quest of a solution, and that the solution is as simple as it should be obvious; we must recreate, in space, the conditions peculiar to the Earth.

There is much to be learned from a study of the ways in which the problems of interplanetary flight are being solved. It appears that success frequently depends on secondary problems seemingly having little in common with the main problem.

Thus we discover that it is not enough to develop a craft capable of overcoming terrestrial attraction and of navigation in empty space. It is not enough to puzzle out all the various details, each of which is essentially also a problem.

Such problems as take-off and landing, piloting in space which offers no resistance to conventional steering gear, cooling of the walls when travelling through the denser atmosphere, have been extremely difficult to solve; especially so the problem of fuel: the size of the required supply has necessitated the use of multistage rockets the idea of which was put forward by Konstantin Tsiolkovsky after twenty-five years of patient effort.

Yet even when the rough outline was seemingly complete a detail was discovered to be missing, without which the entire project was nothing but a romantic dream, and man might have been destined to nothing more than brief sallies beyond the Earth's atmospheric confines, possibly a flight to the Moon at most, were it not for the solution offered by Tsiolkovsky.

The entire early history of the problem may be found in his writings, and the fate of a great discovery is so intricately interwoven with the man's life story that we are naturally led to refer to him again and again.

Tsiolkovsky developed his programme of conquest of interplanetary space while still at work on his multistage rockets, and this programme is set forth with extreme logic in his works.

His programme provides for several stages, the first of which consists in brief rocket-satellite flights with a return to the Earth.

The second stage calls for the installation of a cycle of elements inside the rocket-satellites, similar to that on the Earth, plant life being used for the purpose, since plants absorb carbon dioxide and yield oxygen and can utilise waste and furnish food for human use. A pattern of exchange of energy and matter between plants and human beings is established, or a closed ecosystem, to use the modern term.

The establishment of such an ecosystem makes it possible to implement the rest of the stages of the programme, from the setting up of settlements in the Earth's vicinity, or space stations to use another modern term, to interstellar flights.

The principle of an artificial microenvironment in outer space was fully developed by Tsiolkovsky. His approach, while necessarily only provisional and in general outline, served as a basis for an extremely bold, almost fantastic scheme.

Currently, the second stage of the programme is being implemented, amended in the light of present-day science and technology. Settlements along the lines of Saturn's rings may still be a thing of the distant future, but a manned satellite is now an item of the current agenda. Settlements in the circumsolar space may also be centuries away, whereas journeys to the Moon and the planets may come to be achieved in the not too distant future. Yet even these will apparently necessitate the use of the method suggested by Tsiolkovsky.

Space biologists have developed several specific alternatives. Intent on finding a plant eminently suitable for accompanying the cosmonauts, they have narrowed down their choice to water flora and more particularly, though provisionally, to the chlorella.

The chlorella is highly nutritious, rich in vitamins, and prolific. It is probable that it will become an element of the cosmonaut's rations. In addition it will be a source of oxygen for the cosmonauts.

Neither the chlorella, of course, nor any other marine algae can satisfy all human requirements. Vegetable foods will have to be supplemented with animal products, and it is possible that sea food will be included in the cosmonaut's diet. Other additions to his diet may include mushrooms, poultry and small animals, such as rabbits.

Space stations and spaceships will thus come to be equipped with hot-houses, aquariums and nurseries which will be essential elements of life in outer space, rather than merely reminders of our familiar terrestrial environment.

They will constitute a miniature replica of the Earth, and the similarity will increase as the development of the universe proceeds, space stations are set up, space settlements are established (by future generations), and spaceships begin to take off for distant stars.

It is interesting to note that artificial micro-environments are envisioned in the frozen polar regions as well as in spaceships, space projects, and submarine settlements. Thus, Canadian engineers are working on a project providing for the construction of an air-tight dome on Baffin Land, which will house a population of five thousand. A similar domed settlement is to be set up in the Soviet Arctic; it will be provided with an electric sun and a micro-environment, and it will even have its own subtropical vegetation, a swimming pool and a beach, so that it will hold its own against any summer resort of milder latitudes.

Thus we find that man has been winning round after round in his contest with Nature. The very fact that we are catching up with Nature and going on to create that which hitherto never existed in it is proof of the power of Man's intellect, which makes even the impossible come to pass.

OUTER SPACE AND OCEAN FLOOR

Man, embarked on his programme of reorganising the Earth, has become a cosmic force. The future of the planet is largely in his hands and much depends on his capabilities and plans; and a concept introduced into science a long time ago now carries wider implications.

Vladimir Vernadsky, member of the Soviet Academy of Sciences, and founder of geochemistry, coined the term

"noosphere" to denote the terrestrial layer where man's activities produce a planetary impact. "We are living in a remarkable era, when man is acquiring the characteristics of a geological force that is changing the face of our planet," wrote Vernadsky.

This was written some twenty-five years ago, when the Second World War was in full swing and the trends of the great peaceful achievements of future years existed in barest outline, for the greatest achievements in science and technology were then confined to those that could be used on the field of battle. These included radiolocation, jet airplanes, rockets, cumulative explosions, electronic equipment, and the use of atomic energy.

Even in those days, however, scientists dedicated to the victory of progress saw other things beyond the images on the radar screens, the mushrooming of atomic blasts, and the whine of rocket missiles: in their mind's eye they saw the beginning of another era.

Fighter planes closing in to join battle and bombers winging thousands of miles to deliver their death-dealing cargoes will give place to speedy jet passenger liners linking cities and continents.

Radar will no longer be used to follow naval battles and dog-fights in the sky: it will be used for peaceful navigation, and radio beams will reach out to other worlds—the Moon, and the planets Venus and Mars, detect minute meteors entering the Earth's atmosphere, and seek out thunder clouds.

Hydrophones which picked up the sound of enemy submarine propellers will now be used to listen to the voices of fishes, and hydrolocators—to search for schools of fish rather than lurking submarines. Speaking of submarines: they will carry oceanographic laboratory equipment in place of torpedo tubes and anti-aircraft guns.

Rockets will no longer hurtle over the face of the Earth to blast cities: instead, they will be employed for studying the atmosphere and, later, as spaceships for probing interplanetary space.

Charges of explosives will no longer be detonated to destroy, but rather to throw up dams, build highways across mountain country, mine ores, and work metals. The atomic blast, too, will be harnessed and put to work in electric power plants, in airplanes, ships, automobiles, and trains.

How, we are tempted to ask, does the present compare with the past?

Bit by bit the noosphere spread over the surface of our planet. Virgin soil was ploughed up where conditions were favourable, rivers were made to flow in new directions, forests were planted, deserts, jungles, swamps and forests were brought under control as men widened their living space, and the face of the Earth changed visibly within the life span of a single generation. The boundary line of virgin lands moved ever northward; and new blue areas appeared on the map as vast new reservoirs were created.

Mountains of earth were spaded over in the search for coal and metal. Shafts were drilled in order to tap petroleum fields. Thus the noosphere added mile after mile in its advance into the Earth's interior, and into the topmost layers of the ocean, as deep as the fish nets would reach.

The impact of man's efforts was felt in the atmosphere as well. The forests gave off oxygen, and the factories added carbon dioxide to the atmosphere. Carbon dioxide is one of the elements that regulate the climate, which also felt the impact of the effort of men, whose number had by then passed well over the two thousand million mark.

Nearly a quarter century has elapsed since Vernadsky classified man's activities with the Earth sciences, adding them to the list of the cosmic forces responsible for changes in our natural environment. The changes have been far-reaching, and the noosphere has continued to expand. As a matter of fact its current rate and scale of growth is different from what it was. Much of what the scientists of various lands had foreseen and worked for has come to pass.

It is doubtful if our planet had ever undergone comparable changes. The new dams and canals, reclaimed deserts and swamps, cultivated virgin lands, man-made lakes and seas are indicative of the scale of the effort that we can apply to the task of modifying our natural environment.

Great as they have been, our achievements will seem modest by comparison with what may be expected a couple of decades from now, for the scale of our intrusion into our environment is destined to increase still more.

The relative figures—additional acres of reclaimed land, more millions of kilowatts of hydroelectric energy, and more

millions of tons of mined wealth—are not the only feature to be watched.

Other *dramatis personae* are appearing upon the scene as science and technology join in equipping man for decisive battles against the formidable forces of Nature, such as atomic energy, which he himself has conjured up and is learning to master. This process is bound to push the frontiers of the noosphere outward in all directions, in the near future and on a tremendous scale. It will embrace all of the World Ocean and all of the terrestrial crust, engulf the atmosphere and reach out into the geocosmos and outer space.

The prefix "geo" in the words "geology" and "geography" would seem to perpetuate the association of these subjects exclusively with the Earth; so that such new terms as astrogeography and astrogeology may sound a trifle incongruous. These terms may be imperfect, admittedly, but they are basically correct, for they do reflect the true state of affairs.

We must remember that there has been and will continue to be an interrelationship between terrestrial and cosmic processes. Geographers bent on comprehending the peculiarities of the Earth's surface treat the Earth as a planet, or a cosmic body belonging in the solar system.

They are therefore interested in the origin of the Earth, a problem that pertains to cosmogony and links geography with that subject.

Vernadsky's concept of terrestrial envelopes has been known for quite some time. These envelopes vary from planet to planet, and geography will benefit from their comparative study, becoming an element of planetology, which is a subject of wider scope. Geography, then, is a starting point for this science of planetology.

Men erect monuments to commemorate outstanding events and dates. Thus, monuments have been set up to mark victorious battles and to preserve the memory of men whose deeds should never be forgotten. In the Soviet Union it is becoming a tradition to commemorate in stone or metal deeds of outstanding merit in the field of labour and science. A recent example in the Soviet Union is the obelisk set up to commemorate October 4, 1957, noted for one of the most remarkable feats in the history of science, a date which will be remembered for many centuries for having opened a

new era in the life of our planet with the launching of the Earth's first man-made satellite, the original sputnik.

Never has a product of man's handicraft had as marvellous a career as that small sphere with its long antennas sticking out like so many tentacles.

Its life span was only ninety-four days. It flew off into outer space, never to return. Millions have viewed a replica of this, the first man-made heavenly body. Though the original perished, it will live in men's memory for ages to come.

There was nothing impressive about this modest pioneer of outer space. It was no larger than a big rubber ball, and its burnished metal surface shone like a mirror. Nor was there anything particularly mysterious about its antennas protruding in every direction. Yet people experienced a peculiar feeling as they looked at this thing.

Insignificant in size as it was, by comparison with the planets, the sputnik was a full-fledged member of the solar family. Like the Moon and the rest of them, it obeyed the laws of heavenly mechanics, even though it was made by the hand of man and not a product of Nature. It promoted man to the rank of citizen of the universe and served notice that man would conquer space as he had conquered the Earth.

These minute artificial cosmic bodies revolving in the vicinity of our planet render science an extremely valuable service: they probe the higher layers of the atmosphere, being capable of remaining months and years on end where the ordinary type of rockets cannot remain more than a few minutes.

They relay data on atmospheric density at high altitudes. They can be used for getting information on the Earth that they orbit, regarding its shape, the force of gravity at its surface, etc. They can also serve as navigational beacons, and render aid to geographers by providing more precise data for the map-makers and measuring with great exactness the distances between any given points on our planet.

Just as pilot-balloons and radio sondes are used by meteorological stations to study weather conditions and compile weather forecasts, so will satellite-sondes be used to function in outer space, where there is no weather. They will have a lot of things to do. Thus, a solar service, a cosmic ray service, a meteor and cosmic dust service, a polar auro-

rae service, a terrestrial magnetic field service, and a terrestrial cloud canopy service will be entrusted to the satellite-sondes.

Continuous observations will be carried on and recorded on magnetic tape, and the accumulated data will be transmitted to the Earth as the space laboratory flies over a receiving station, so that there will be a rapid and constant flow of information down to the Earth. This will bear some resemblance to weather reconnaissance, but with the difference that a single satellite's prolonged sojourn in space is worth a thousand laboratories on the Earth.

When the batteries go dead, when the transmitter becomes silent and the satellite perishes, new satellites will take its place. Moreover, some of these new satellites will be of gigantic size; they will orbit the Earth and approach the Moon.

Only a few years have gone by since the first Soviet satellite appeared in the sky, and already we have developed a matter-of-fact attitude towards these launchings, and cosmonautics in general is now taken for granted.

Men have already travelled in space; the state of weightlessness is no more a novelty; the interior equipment of spacecraft has become familiar; we are proceeding with the exploration of near space; and we have begun to probe outer space as well.

What will this intrusion into the cosmos lead to? What will be accomplished and when? It is difficult to make any forecasts, but it is possible that achievements will materialise sooner than we might expect, and it is also possible that they will materialise in different, perhaps more perfect forms than might be foreseen.

Supposing we try to outline the probable general trend of developments, starting in the foreseeable future (before the end of the current century, let us hope), and assuming that a good part of the road ahead has been travelled and a foothold has been established on the Moon.

The groundwork for that has already been laid by the work done since the late fifties. The pennants delivered to the Moon, the photographs transmitted back to Earth by the lunar probes, and, finally, the first soft landing on the Moon by the Soviet Luna-9 automatic station, which sent

back closeups of the Moon's surface, all bring nearer a manned landing and direct exploration of the Moon.

Lunar settlements, hitherto a favourite topic of science-fiction, have rather imperceptibly found their way into purely scientific writings. Astronomers, for instance, dwell on this topic with obvious enthusiasm born of great expectations.

To begin with, the Moon affords excellent opportunities for astronomic observation, and many scientists stress its advantages as an observatory over any other facilities, for it offers terra firma underfoot, and obviates the nuisance of weightlessness, because gravitational attraction does exist on the Moon, even though to a lesser extent than on the Earth.

The Moon has more to offer in the way of shelter or protection than a man-made space settlement. Underground dwellings and facilities will provide shelter against the cold of the fourteen-day lunar night and the heat of the equally long lunar day, as well as against radiation and meteorite bombardment. Other approaches to the lunar settlement problem may be offered, of course.

Oxygen will probably be obtained from local rock; water will in all likelihood also be found in minerals; and ice may possibly be present. Food will have to be flown in from the Earth until such time as the cosmic hot-houses begin to yield crops. As to energy, finally, this will be supplied in sufficient quantity to meet all requirements of the scientific settlement by a helioelectric power plant.

Should it be found possible to produce rocket fuel on the Moon, the lunar settlement would become a permanent base from which automatic and, later, manned spaceships would take off on distant journeys.

It is reasonable to ask at this point why we should be at all interested in lunar settlements. If it is a matter of raw materials, don't we have enough here on Earth and must we look for them in outer space? The development of cosmonautics calls for a heavy investment of human effort and means. But is this investment worth what we might find on the Moon?

We must turn to the selenologist, the engineer and the economist for the answers to our questions.

It is the job of the selenologist to explore the Moon in the same manner that we have explored the Earth and to deter-

mine what the Moon's interior may contain. The discovery of valuable minerals, rare elements, or petroleum (its presence is not excluded) would be one argument in favour of continuing our lunar programme.

Before we proceed to sink mines on the Moon, however, the engineer must tell us whether he is capable of building the machinery and facilities for actually mining the ores and flying them to the Earth. There is a difference between sinking shafts in the floor of our oceans and up in the Moon. If the engineer answers in the affirmative, we shall have a second argument in favour of our programme.

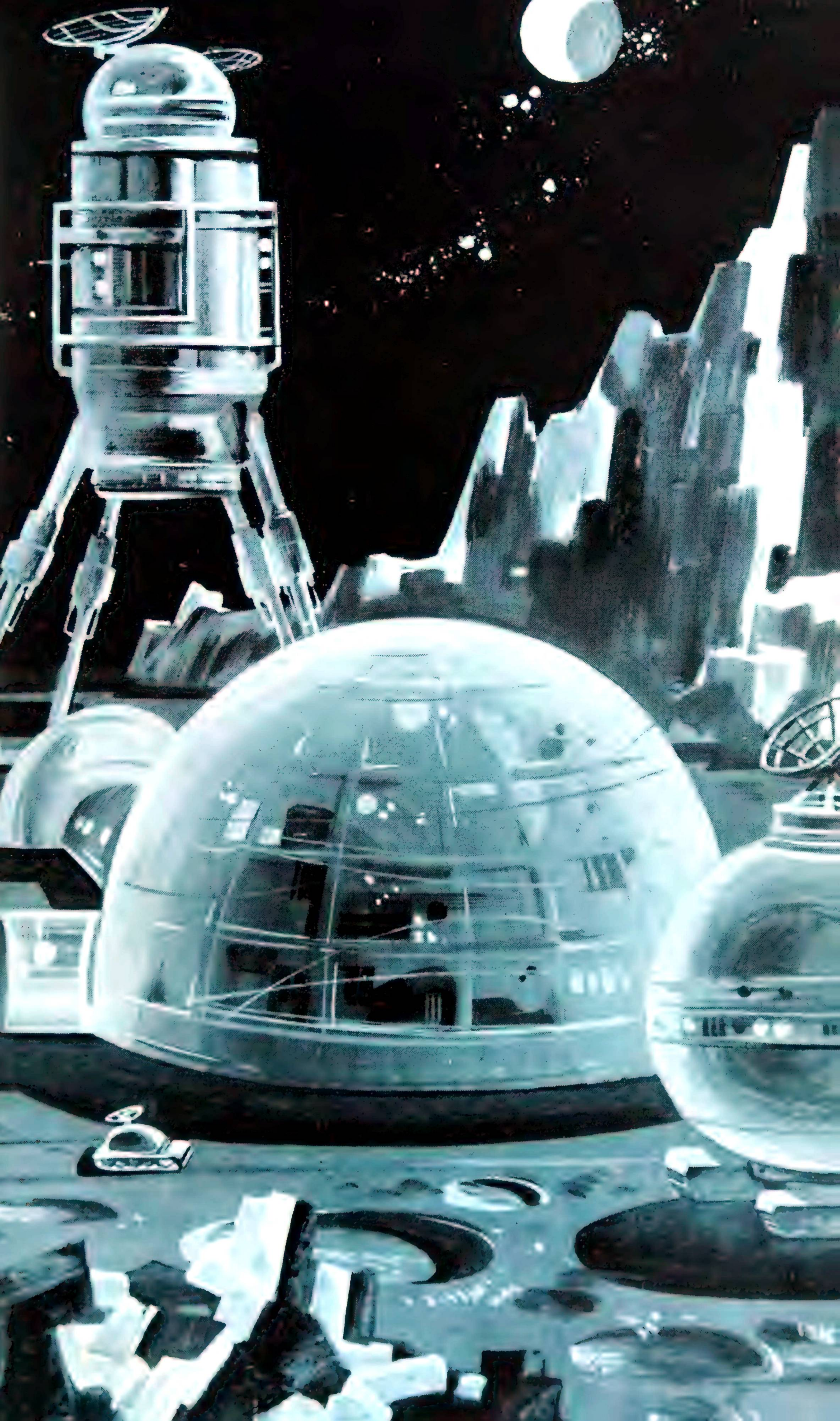
The two arguments will still be insufficient, however, to tip the scale in favour of our lunar programme, for the difficulties ahead are very great and very unusual, and mere faith in the power of the equipment to be developed is not a conclusive argument. Much will depend here on the pronouncement of the economist.

Again, one might wonder if we must continue being economical in the future, when we shall have an abundance of energy and when machines will shoulder most of the labour hitherto performed by man.

We shall certainly have to do so, for abundance does not imply waste. Moreover, it is not a question of financial outlay alone: the lunar development programme will require the overcoming of exceptionally great impediments, perhaps even the sacrifice of human lives, besides vast financial investments. Nevertheless, if these great projects are finally judged to be worth while, they will be carried out.

Once the decision is made, rockets will fly in everything that is needed to proceed with construction. Settlements will go up among the craters and cirques of the lunar surface. Drills will start sinking shafts to established deposits of ores and petroleum pools. Cross-country lorries will travel newly built roads, hauling lunar raw materials from locally constructed plants to the cosmodromes, from where these materials will be flown to the Earth to feed terrestrial industries.

The future settlement on the Moon will be outpost of science in the universe and rocket-launching site for cosmic fligt Spherical cross-country vehicles will be us to travel over the Moon's roadless wastes



Speaking of transport for use on the Moon: this problem is receiving serious attention on the part of scientists, even though it is a bit too early to set any dates for man's first landing on the Moon.

An interesting cross-country vehicle has been suggested for lengthy sorties over the Moon's roadless surface.

This is to be a huge sphere made of a double layer of durable tissue with a thermal insulation lining. It is to be delivered in folded form by rocket. A broad pneumatic-rubber encircling rim will help the vehicle roll across such obstacles as fissures or humps. Run by electric motors, it will look like a gigantic wheel set off on top with the large screen of a semiconductor solar battery.

This globe will be a sort of mobile lunar station, equipped with everything required, including a TV set and a combination hothouse-aquarium of its own for growing algae for the double purpose of supplying nutrition and impregnating the atmosphere with oxygen.

Several other types of vehicles for lunar travel have been developed in recent years.

Rough terrain may take a variety of forms. Caterpillar-tracked cross-country vehicles capable of traversing level land will mostly have to face steep mountainsides, chaotic boulder accumulations, ridges, and crevasses, which they will be unable to tackle.

Hence the idea of a walking cross-country vehicle, able to travel where a caterpillar tread is useless; also a vehicle equipped with huge spherical wheels, capable of getting over obstructions. Nor are caterpillar treads neglected, only they are attached to the feet of the walking vehicles.

The field for invention, in other words, is boundless, for until such time as a network of level roads is built on the Moon we shall have to evolve the kind of transportation facilities that will aid us in studying and developing the entire mountainous area of the planet.

If fuel can be produced locally, a type of rocket ship capable of flying in vacuum will be found useful, since it will be able to stop and remain suspended, so that the pilot may observe and photograph the landscape below.

A combination cross-country rocket vehicle is another possibility. It would be able to leap over hills and reach otherwise inaccessible places; its caterpillar tracks and feet, or

both, or else its wheels would make the entire planet accessible.

Robot vehicles can also be used for exploring worlds other than ours. Lunar cross-country vehicles can be piloted by a robot that would be given the course to follow. Solar batteries would drive its motors.

Its mechanical grab-arms would collect rock samples, and its automatic drilling rig would obtain underground probes, which would be analysed on the spot, so as to give immediate information on what type of rock is to be found at such and such a spot. The exact location, incidentally, would be established by the operator observing the vehicle's work on his TV screen as distinctly as if he were actually on board the vehicle. As a matter of fact, operation of such a robot vehicle by radio from the Earth is not excluded.

Such remote control, leaving the vehicle unattended, is extremely risky, however, for should the vehicle become stuck in a crevasse or otherwise damaged the effort would be a complete failure.

Occasionally the suggestion is made that conditions similar to those on the Earth might be created on the Moon; that the technology of the future—and we mean the distant future, of course—could create an atmosphere around the Moon, build water reservoirs, plant vegetation, in short, bring the Moon to life. Unfortunately, that is impossible. There is no way of changing the Moon's gravitational attraction, which is too insignificant to retain the air essential to all life. Life will be possible only in man-made lunar oases, where conditions will resemble those obtaining on the Earth.

Let us now hear what the scientists have to say about the other neighbouring planets.

We shall begin with the planet Mars.

Its vegetation may be unique (astrobotanists think it might be pale blue), but it resembles that on the Earth; the atmosphere may be rarefied and deficient in oxygen, but it is an atmosphere composed of air and not ammonia as on the giant planets. This planet of a reddish tint is one where life is either already extinct or not yet ready to begin.

Perhaps these conjectures are somewhat bold. The truth of the matter, however, is that Mars is the only one of the planets that really promises to have life, even if that life may assume rather simple forms.

Venus seemed to hold forth such a promise in the past. As a matter of fact, there was a tendency to picture it as the Earth's younger sister, with life in full bloom, as it had been on the Earth after leaving the ocean and overrunning dry land. Fantastic fiction has travellers discovering tropical forests on the planet, hunting huge lizards and pterodactyls, and coming across primitive ape men.

Robot rocket flights in outer space exploded this myth that had seemed so credible. It seems that Venus has too hot a climate to allow the kind of life that had been conjured up by the fiction writers, so that any expectation of encountering prehistoric monsters upon it has had to be given up. One wonders what the cosmonauts may find beyond the cloud canopy of this bluish planet. Whatever it is, it can clearly be nothing like life on the Earth.

Meanwhile, Mars continues to draw the attention of those who are on the lookout for planets similar to ours. Here again, however, it is no use trying to guess what we may find on it. One may definitely expect, on the other hand, that if our conjectures regarding the presence of oxygen, moisture and vegetation in the bleak Martian deserts turns out to be correct, we shall certainly undertake to transfigure that planet.

Moisture shall first have to be found, and if there is not enough, then an artificial supply shall have to be established. This is where the chemists come in, for Martian rock probably contains enough raw material in a bound state. The deserts' reddish hue leads us to expect the presence of oxides, from which oxygen could be obtained. Hydrogen is more of a problem, but it is the most ubiquitous element in outer space and is bound to crop up somewhere on the planet.

We shall thus have enough to begin with. Also, there is the possibility of running across ice at some place or other, inasmuch as polar ice caps are known to exist on Mars.

Water distribution shall have to be planned with great care to provide for the vegetation, both the Martian, which remains hypothetical, and the very real terrestrial kind that we shall plant on the planet.

The vegetation will supply oxygen and absorb excess carbon dioxide from the atmosphere. It has been estimated that the density of the atmosphere will increase to such an extent

that people will stop using oxygen masks. The early settlements will possibly be set up underneath protective domes, but by and by the environment will approach that on the Earth.

Mars will still be easier to develop than the Moon. No special type of transport will be called for, since there is no inaccessible mountainous terrain on the planet, and the ordinary type of cross-country vehicles will be able to traverse the Martian plains.

The harsh climate will be a hardship, to be sure. Solar radiation reaches Mars in meagre quantities. Still, it is within the realm of possibility that later generations will light a man-made thermonuclear sun over the planet, once it begins to come to life. Or perhaps a string of semi-conductor helio-electric power stations will be set up around it, assuring copious energy and therefore plentiful heat.

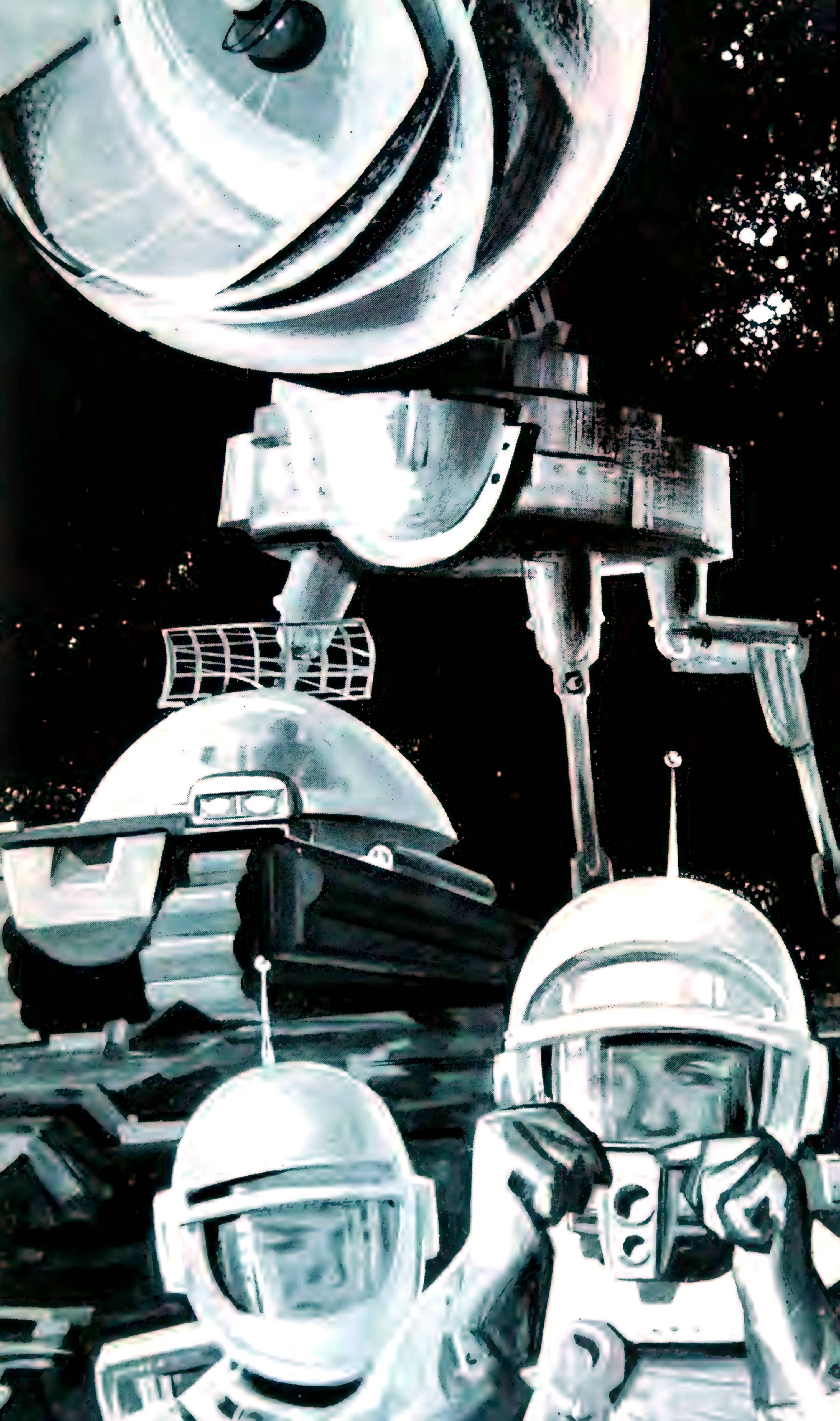
Nikolai Semyonov, member of the Soviet Academy of Sciences, considers that thermonuclear energy is the key to creating an oxygen atmosphere around Mars, obtaining water, and generally making the planet suitable for terrestrial life. The truth is, however, that this would require ten thousand times the energy currently produced on the Earth.

There is a chance at the same time, that no such radical reorganisation of the natural environment on Mars will be needed in order to make it habitable for human beings and plants brought in from the Earth.

According to the findings of biologists, for instance, some species of terrestrial cultivated plants have shown remarkable adaptability to quite exceptional and rigorous conditions. Thus, they have been deprived of oxygen or allowed an extremely meagre supply of this gas, or else given argon or nitrogen instead; they have been placed in rarefied atmospheres; and subjected to very low temperatures. It was like transplanting them on Mars, in other words.

Surprisingly enough the plants thrived, including even the warmth-loving cucumber, which developed excellently in an argon atmosphere and survived frosts, which is quite unusual for it. Tomatoes, lettuce, beans, turnips, and other plants sprouted as soon as a little oxygen was supplied. This suggests that we may be wrong in thinking that the Martian vegetation is limited to lichens and dwarf scrubs. Perhaps

The planet Mars will be explored and dev oped



there is a unique, thriving and varied vegetation on the planet, after all?

It is possible that in the future, when the rockets reach the asteroids belt, men will utilise these minor planets, which, together with solar energy, were seen by Tsiolkovsky as the greatest source of wealth in the universe.

These minor planets would furnish excellent building material for cosmic industry. They constitute tremendous resources of chemicals available for space settlements and for our own use here on the Earth. Mars, incidentally, might well become an advance base for the conquest of the asteroids belt, which is within comparatively easy reach from the planet.

It is rash to be definite at present in regard to the planets farthest away. If colonies are ever established on the fringes of the solar system, it will probably be on the satellites of the giant planets, and even then they will mainly serve as observation stations.

Mercury, which is nearest to the Sun, promises to become a source of pure metals for us. Here, too, a solar observatory will be set up to assure continuous observation of the Sun from a closer point.

Assuming affirmative answers from the planetologist, the engineer and the economist, we have been discussing the development of other worlds, both near and distant. Yet there is another aspect to the problem, as interesting as it is important, that merits attention.

Will the planets yield any other benefits besides ores and metals?

Undoubtedly they will. Perhaps the greatest benefit that we can get out of cosmonautics is knowledge.

The Earth is a part of the universe. A greater knowledge of the whole means a greater knowledge of that part, paving the way to its reconstruction.

When the conquest of the solar system will have been achieved, the best possible use of the material wealth and knowledge gained will be made here on the Earth.

New fields of biological experiment will open up, leading, possibly, to the enrichment of our cultivated plant species. The biologists of the future will apply themselves to such problems as the crossing of terrestrial plants with extra-terrestrial varieties, and the effects of radiation, low gravita-

tional attraction, weightlessness, and intensive sunlight in space green-houses. New forms of life, different from those on the Earth, in the world of microbes, for instance, might also be used to good purpose.

All that is for the relatively near future. Prospects for the remote future are in the realm of pure fantasy.

There is no foreseeing the actual possibilities that will be opened up by interstellar flights, intergalactic communication, and cultural exchanges between our civilisation and the civilisations of other worlds. We can discuss the technical aspects of such flights and communications, we can estimate the probability of encounters with the unknown inhabitants of unknown planets, but any speculation as to the possible consequences will still belong to that realm of the fantastic.

One of the prospects must be mentioned here, however, though it, too, is on the fringe of fantasy and is enough to set one's head awhirl. Yet it was stressed by Tsiolkovsky, and other scientists have written about it.

The flight of their imagination carries them aeons away, to the time when visible changes of cosmic proportions will begin to overtake our planet. Here, too, various hypotheses are advanced, depicting the Earth (millions of millions of years from now) either as succumbing to a new glaciation or completely transformed into a steaming ocean.

For the Sun, as we know it, won't always be with us. Nor other things, either. Nothing, it has been said, is eternal under the Moon; and the Moon, too, will not last for ever: right now it is drawing away from the Earth, but at some time in the future it will begin to draw closer again, only to break up finally into numerous fragments. Our planet will then acquire a ring, just like Saturn's. All this is to happen not earlier than 1,000,000 million years from now, however.

The Sun is bound to die in the long run, and there is nothing incredible about the fact. It is an ordinary star, and it will meet the same fate as the others. Among the countless stars, some perish and new ones are born. So with the human race, which will not perish, but will inevitably reappear somewhere in the boundless universe.

What about the Earth itself? How will the human race fare in the era of the Sun's decline? Is it possible that mankind with all its wealth of power resources and material wealth must also perish?

The answer can and must be in the negative, even if we cannot know how science and technology will develop in the very remote future.

Men will undoubtedly discover the means of fighting off any spectacular planetary catastrophe. When they find themselves deprived of their accustomed environmental conditions they will recreate them artificially: new, man-made suns will be set ablaze and artificial oases capable of sustaining life will be created.

Let us assume for the sake of argument, however, that life will become impossible on our devastated planet. It is possible that a natural and inevitable end awaits the Earth, like the countless other worlds of the infinite universe.

Should we then accept mankind's end as predestined and seek consolation in the continuity of life and the immortality of the intellect? The answer is an emphatic "no"! Tsiolkovsky was the first to voice this opinion.

The Sun may go out, but the human race will never perish.

Our rockets will conquer the infinities of space and our spaceships will blaze a trail to other stars. Men will set out on the quest for other suns at the apex of their development and re-establish life on their satellite planets; for there are enough suitable stellar systems available to offer us a home. The human race will thus be destined to migrate from sun to sun, for suns may come into existence and burn out, but the seed of intelligence will live for ever and its advancement will be endless.

This need not be construed as a call to flee our planet and resettle somewhere in outer space, not even in millions of years. Suggesting this way out, Tsiolkovsky was concerned with the fate of the generations that would succeed us thousands of millions of years from now.

* * *

Meanwhile other tremendous schemes, concerning the Earth, rather than outer space, are coming to the fore more and more frequently. These, too, will demand the participation of all of us and can be implemented only by mobilising all our scientific and technological resources.

While we dream of tapping the metals and petroleum of other worlds we cannot afford to overlook the wealth of

our own planet. Nor can we–while developing plans for lunar, Martian, and other similar settlements–afford to overlook a location much nearer at hand: the ocean floor.

The several dozen deep submergences carried out in the past are a drop in the bucket by comparison with what remains to be done if the ocean depths are to be pioneered and developed. Existing single specimens of mesoscaphs, diving saucers and all types of submarines for the upper layers can no more than initiate the plan of developing a research fleet. Hydrostats are but the prototypes of permanent submarine scientific stations. And the first settlements on the floor of shallow waters may be likened to a timorous first step towards the implementation of our programme.

An eight-kilometre shaft is a mere pin prick on the terrestrial surface, because it does not pierce even the outer shell, which is aptly likened to the shell of an egg or the skin of an orange.

Pioneering of the deeps has been going on for some time. The first record dives were brilliant episodes, but they belong to the past, albeit quite recent. Exploration of the ocean will naturally be continued.

Tentative ventures with the newly invented aqualung have become a favourite sport, thanks to which we have pioneered the fringe of the ocean and learned quite a bit about it. The diving saucer has taken us to the edge of the continental shelf, and mesoscaphs will help us study the life and resources of the medium depths. When the new bathyscaphs are built we shall reach the ocean's deepest trenches.

Men will gradually learn to exercise a certain amount of control over life in the ocean depths. It goes without saying that this incursion must be performed with intelligence and circumspection, and will require a thorough study of life in the depths. Ichthyologists are even now using the full range of available equipment to penetrate the ocean, such as the aqualung, surface craft, hydrostat, mesoscaph and bathyscaph.

Experiments with transporting the young fry of fishes from one body of water to another will be succeeded by other experiments. Unique hatcheries will be established in coastal areas where the fingerlings will be hatched, fed and protected in special reservoirs. When grown, they will be released into the ocean, though there, too, they will not be allowed to fend for themselves.

The important point is that a system of close control will be established over fish populations, similar to that over valuable animals or farm stock. Haphazard extermination of these populations will be stopped. The aim should be to accent fish breeding rather than fishing and to establish intelligent planning in regard to our marine life resources as a part of our overall economy.

Looking ahead, we can see submarine trawler bases sailing for predetermined locations, accompanied by fleets of submarine trawlers. These will no longer cast their nets trusting to blind luck, for hydrolocator posts will spot the location of schools of fish and report to the trawler bases. The voices of fishes, artificially reproduced, will serve as a new kind of bait.

Trawlers will operate at great speeds, filling their trawls, delivering the catch to their base, and going off for more. They will never return empty handed. Fishing will spread to new areas of the ocean, never fished before, expanding in all directions, depth included. Whales, too, will be hunted by submarine whalers instead of being harpooned on the surface.

Our approach to the development of marine vegetation must also be very cautious.

Plantations of seaweed will probably appear along the coasts. As greater and greater submarine areas are brought under cultivation agriculture will, in a manner of speaking, spill over into the ocean. Engineers are already working on the problem of securing a firm foothold in shallow waters as a beginning.

It is hard to list at present all the benefits that we may get out of such farming on the ocean fringe. Seaweeds, for instance, mean a variety of foods, spices, raw materials, and medical substances. As a food product seaweeds have more to offer than plankton, which, too, is currently receiving serious attention.

There is another remarkable aspect to seaweeds, which should not be passed unnoticed. They are actually a kind of living biochemical laboratory: in addition to the process of photosynthesis which goes on in them, they accumulate certain elements which they draw from the water. Gold may, admittedly, be discovered in corn, but it is the algae that are outstanding as bioconcentrators.

It is perfectly logical, therefore, to picture plantations of

"living ores" springing up in shallow waters along the coasts. Whatever their possible yield may be, and that is a different matter, it is probable that extraction from sea water with the aid of plants will prove the most economical method in regard to the more valuable elements.

Bacteria may be utilised for this purpose, provided we are able to breed species capable of accumulating selectively the particular element desired. Bacteria breed with incredible rapidity, and it is possible that we shall learn, in time, to create placers of various ores, just as nature creates concretions but much faster, not over millions of years. This would mean a potential source of badly needed raw materials, for the ocean contains a vast supply of metallic ores.

We shall have recourse to chemistry, too, once we begin developing the riches of the seas. Current achievements in the field of chemistry give us assurance of still greater successes in the time to come. This has an especially important bearing on the gold to be obtained from sea water. We have taken up this subject of gold because the hunt for gold in the ocean began a long time ago. The cost of the method used, however, far exceeded the value of the gold thus obtained. The quest thus ended in failure because no simple and, what is very important, cheap method of obtaining gold from sea water could then be discovered.

Were millions of tons of precious metal to remain for ever inaccessible to man in that case? The answer seemed to be that they were, for the gold is still there, in the sea. Yet we must not jump at hasty conclusions.

To be sure, the gold fields of the ocean are yet to be tapped, but experiments are under way: the first grains of gold have already been obtained under laboratory conditions out of the gold dissolved in the ocean.

Perhaps it is premature to envision the time when gold will be produced in great quantities and will have therefore lost its exceptional value. But right now even milligrammes must be regarded as a great achievement.

Milligrammes imply infinitesimal quantities that can be discerned only with a microscope. On the other hand, it takes several cubic metres of water to produce even so negligible a quantity. Therein lies the production problem.

A Soviet research vessel recently sailed into the Pacific to become the first seagoing chemical plant of its kind in

the world. It may be too much to call it a chemical plant. That was only the first experiment, though it was actually definitely successful. The product, obtained from ocean water, barely covered the bottom of the test tube and required very fine scales to weigh it. Still, a beginning is often quite modest. Aluminium, for instance, was once mined in such negligible quantities that it was classed as a precious metal, and now its output runs into millions of tons.

To solve this problem of production we must turn to ion exchangers, which capture even the minutest quantities of a substance, atom by atom, much like a very fine sieve.

An ion-exchanger molecule is composed of charged particles with the opposite sign, some of which are capable of passing into a solution by changing places with the ions of the dissolved substance. Particles of ion-exchange resins have the property of attracting ionised atoms. Ion-exchanger spheres, rods, and membranes capture minute elusive quantities of the desired substance lost in the innumerable molecules of water. When, however, hundreds and even thousands of cubic metres of water impregnated with a variety of admixtures are filtered, those minute quantities become sizeable.

The many-hued grains of ion-exchange resins, hard, impervious to water, acids, alkalis, and oxidisers, ready to do the necessary job at a moment's notice, year after year, are one of the most remarkable achievements of the current century in the field of chemistry.

Ion-exchangers do not dissolve when immersed in water, but they do swell through the absorption of water, and it is inside their swollen grains that the exchange takes place and the ions desired are selected and the unwanted rejected. This selectivity is one of the remarkable properties of ion-exchange resins.

There could be no sorting out of molecules were it not for this property of selectivity, and ion-exchangers could never play their role, which is of such importance that the discovery of ion-exchangers may well rank with the other outstanding discoveries of the current century.

Let us now assume that the ocean and the ocean floor have been rather thoroughly pioneered, and let us picture ourselves on a submarine, outward bound on a visit to an underwater scientific station.

We have long since left the layers of water where the light of day still lingers on, and we are travelling through the realm of eternal darkness. Pale specks of fire light up and go out from time to time as we pass some denizen of the ocean's deeper layers. As we approach the bottom, stationary clusters of much more brilliant lights appear out of the dark.

Our submarine is nearing its destination, a scientific station set up on the ocean floor. Our searchlight reveals the outlines of a building and a huge metal cylinder standing in the middle of a submarine valley, and we vaguely discern at its base a network of girders which forms the settlement's characteristic foundation. Rows of lighted observation ports appear, and a ladder leading from the ocean floor up to the lock-chamber; a pier is visible farther off, alongside which we make fast.

After a while we step down on the bottom, wearing our deep-sea equipment and lighting the way ahead with searchlights mounted on our helmets. One by one we go up the ladder, and the lock-chamber door shuts behind us. When the water drains out completely we take off our divers' outfits.

We find ourselves next in a laboratory equipped for studying the lower depths. The scientists who work here belong to the oceanographic services. Submarines and cross-country motors use this base as a starting point for underwater journeys of exploration. Submarine geologists are busy prospecting the ocean floor with a view to tapping the resources beneath it. There is work here, too, for zoologists, biologists, physicists, and hydrochemists, for if the secrets of the submarine world are to be unravelled continuous observation of all the complex processes throughout the World Ocean is necessary.

Laminated wall construction with a liquid core capable of withstanding the pressure of the water outside ensures the safety of the settlement's inhabitants. Portholes provide good observation. Searchlights and flood lighting are available. The building's several floors house the living quarters, service premises, laboratories, storerooms, workshops, power plant, and data-processing centre.

The station receives and processes reports coming in from numerous automatic observation posts scattered over the

ocean floor and buoys anchored at various depths. Communication is effected by means of ultrasonics. Here, too, various water, soil and concretion samples are assembled. Various data are also collected to aid in perfecting maps of the invisible continent, to ascertain the distribution of its resources and spot underwater currents.

Fantastic benthic fishes and plants are not the only things to draw our attention as we continue our voyage. All kinds of craft continuously pass by, such as cargo and passenger submarine liners, fishing trawlers, whalers, cable ships, and seaweed harvesters. Pioneered by now from surface to bottom, the ocean has ceased to be an alien environment.

The facilities and equipment of the ocean economy are very diversified. Automation is widely used. Distant machinery and robot bathyspheres, for instance, are operated by remote control. Drilling rigs, petroleum and gas wells are in production under water. Pumps and draglines are used to scrape up metallic ore accumulations, found scattered over the bottom of seas and oceans.

We see numerous automatic stations as we travel onward, both on the ocean floor and at different levels. Some of these are equipped with TV for observing the surrounding scene, others have seismographic equipment capable of recording and transmitting data on submarine volcano eruptions and quakes.

Submarine autogiros and giant bathyscaphs are also at work in the ocean depths. In addition to observing and studying life at hitherto inaccessible depths, they engage in deep-sea fishing, attracting fish and marine animals with sound and using either special types of harpoon guns or simply sucking them into a mouth-like trap in their hulls.

Thus we find the World Ocean finally mastered by man, who has tapped its riches and proceeded to effect its reorganisation. He has changed the pattern of ocean currents, warmed the waters of the Arctic, changing the climate in hitherto frigid regions. He is breeding valuable species of fish, protecting them from predatory varieties, providing them with food, and helping them become acclimatised in new localities. He is using seaweeds to obtain valuable elements from sea water, and plantations of marine vegetation now cover the coastal shallows.

He has tapped the ocean's inexhaustible power potential, such as the tides and the temperature gradient, and obtained from it the raw materials for thermonuclear power plants.

Man has invaded the ocean floor, and the petroleum production derricks which had begun by marching out to sea have gone on to disappear beneath its surface, so that underwater petroleum extraction has now become underwater in the strictest sense of the word. The pressure of the water column now forces petroleum and gas up to the surface.

As to mining, it is premature to attempt guessing whether geotechnology will be called upon to play its part in submarine mines, but it is certain to play a leading role, in time, in mining operations on land.

Alexander Fersman, member of the Soviet Academy of Sciences, visualised our planet as riddled with mines to resemble the pores of the skin, and thought that chemistry would control the Earth's atmospheric envelope. Let us hope that the World Ocean, too, will serve mankind on the planet that it shall have reorganised and brought completely under control.

REQUEST TO READERS

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